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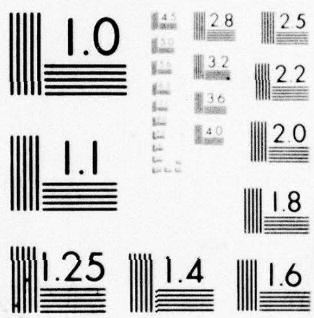

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REPORT JTCG/AS-74-D-002

FIELD OF INTEREST: 01–18

JTCG/AS

PROPOSED MIL-STD-XXX

AIRCRAFT NONNUCLEAR SURVIVABILITY/ VULNERABILITY TERMS

October 1976

Prepared for

JOINT TECHNICAL COORDINATING GROUP
FOR
AIRCRAFT SURVIVABILITY

FOREWORD

This report summarizes the results of research performed under Contract F33615-73-C-3150. The contractor was General Dynamics Corporation, Fort Worth, TX. The work was conducted through July 1974, and V. L. J. Di Rito and N. Papke were project managers/monitors.

The work was sponsored by JTCG/AS as part of a 3-year TEAS (Test and Evaluation Aircraft Survivability) program. The TEAS program was funded by DDR&E/ODDT&E. The effort was conducted under the direction of the JTCG/AS Design Criteria Subgroup as part of TEAS element 5.1.8.1T, *Military Standard, Definition of Survivability/Vulnerability Terms*.

Much work has been accomplished over the past years to assess and enhance nonnuclear combat survivability of U.S. aircraft. Most of these efforts were accomplished independently by various government agencies and industry. A close technical working relationship and clear communications have been difficult to achieve because of inconsistent terminology relating to the aircraft nonnuclear S/V (survivability/vulnerability) discipline.

To resolve these problems: (1) a well-defined framework of the S/V discipline was developed, (2) appropriate and specific S/V terms were analyzed, (3) inconsistencies and ambiguities were resolved, and (4) the terms were defined accurately.

A proposed Military Standard has been developed that contains consistent definitions of S/V terms and is presented, under separate cover, as an enclosure to this report.

DISCLAIMER

Estimates in this report are not to be construed as an official position of any of the Services or of the Joint DARCOM/NMC/AFLC/AFSC Commanders.

NOTE

Information and data contained in this document are based on reports available at the time of preparation, and the results may be subject to change.

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S/V definitions

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

See reverse side.

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This document established standard definitions for aircraft nonnuclear S/V (survivability/vulnerability) terms so communication problems that have confronted S/V practioners and workers in allied disciplines, in government agencies and industry, can be resolved.

The terms and definitions contained herein shall be used, as applicable, in all Department of Defense studies, reports, statements-of-work, and other documentation involving nonnuclear aircraft S/V.

Proposed MIL-STD-XXX, consisting of 159 pages, is an enclosure under separate cover.

INTRODUCTION

To provide the vehicle for effective and nonambiguous intra- and inter-disciplinary aircraft survivability/vulnerability communications, a study was performed and a proposed MIL-STD was developed. MIL-STD-XXX is included as an enclosure under separate cover.

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This document established standard definitions for aircraft nonnuclear S/V (survivability/vulnerability) terms so communication problems that have confronted S/V practitioners and workers in allied disciplines, in government agencies and industry, can be resolved.

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PROPOSED MIL-STD-XXX
22 July 1974

This draft, dated 22 July 1974, prepared by General Dynamics' Fort Worth Division, has not been approved and is subject to modification. DO NOT USE PRIOR TO APPROVAL.

MILITARY STANDARD

AIRCRAFT NONNUCLEAR SURVIVABILITY/VULNERABILITY TERMS

PROPOSED MIL-STD-XXX

DEPARTMENT OF DEFENSE
Washington, D.C. 20301

Aircraft Nonnuclear Survivability/Vulnerability Terms

MIL-STD-XXX

1. This Military Standard is mandatory for use by all Departments and Agencies of the Department of Defense.

2. Recommended corrections, additions, or deletions should be addressed to: Chief, Survivability/Vulnerability Branch, Prototype Division, Air Force Flight Dynamics Laboratory, Wright-Patterson AFB, Ohio 45433.

FOREWORD

Much work has been accomplished over the past years to assess and enhance the nonnuclear combat survivability of U.S. aircraft. Other efforts have been directed toward determining the effectiveness of U.S. munitions against enemy aircraft. At first, most of these efforts were accomplished independently by various government agencies and industry. As these organizations worked in their respective fields they found that they had similar goals and that a technical interface would be advantageous to all parties. However, a close technical working relationship between these diverse groups has been difficult to achieve because of the lack of a consistent terminology relating to the total activities and elements of the nonnuclear aircraft survivability/vulnerability (S/V) discipline. In fact, an abundance of terms with different usages and definitions had been created. This resulting communications problem was not limited to activities within the field of the S/V discipline but was evident in technical intercourse with other disciplines as well. The basic cause of these problems can be traced to the absence of an organizational framework for defining the interrelationships between all the activities and elements that comprise the total S/V discipline. Since no framework of this nature existed, individual S/V analysts and authors independently developed terms and definitions in order to satisfy specific problems.

Accordingly, the first step in resolving these problems of communications required the development of an exhaustive, well-defined framework or structure of the S/V discipline. This would then solve the primary communications problem - confusion concerning the elements and activities of the S/V discipline. Given such a framework, in the second and final step, appropriate and specific S/V terms could be analyzed, inconsistencies and ambiguities could be resolved, and terms could be rigorously defined and integrated into this framework.

This later body of terms would then serve to illustrate specific activities, elements, or concepts. Properly documented, this total set of terms, definitions, and organizational format could provide the necessary vehicle for effective and nonambiguous intra-and inter-disciplinary communication.

This Military Standard contains this required information: (1) an organizational framework (called topical fields and subfields), (2) definitions and usages for the terms that comprise this framework, and (3) definitions of specific S/V terms and their placement and use in the S/V framework.

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1. SCOPE

1.1 Purpose. This document establishes standardized definitions for aircraft nonnuclear survivability/vulnerability terms so that communication problems that have confronted S/V practitioners as well as workers in allied disciplines, both in government agencies and industry, can be resolved.

1.2 Application. The terms and definitions contained herein shall be used, insofar as they are applicable, in all Department of Defense studies, reports, statements-of-work, and other documentation involving nonnuclear aircraft survivability/vulnerability. This standard is intended for use by industry and government agencies engaged in any activity that involves any aspect or element of nonnuclear aircraft survivability/vulnerability. The activities and elements that comprise the total S/V discipline are described in Section 4.

2. REFERENCED DOCUMENTS

The following document contains some additional terms and definitions applicable to the general areas of interest:

> Dictionary of United States Military Terms for Joint Usage, The Joint Chiefs of Staff, Washington, D.C., JCS Publ. 1, 1 January 1966.

3. DEFINITIONS

The terms and definitions set forth below provide a selected set of terms which offers concise definitions of key S/V concepts required for use of the Military Standard. In some cases, a detailed definition of a term is also given in Section 5. These terms are preceded with an asterisk

Survivability

The capability of an aircraft to avoid and/or withstand a man-made hostile environment without sustaining an impairment of its ability to accomplish its designated mission.

*Survivability Enhancement

The use of any tactic, technique, or survivability equipment, or combination of techniques that increases the probability of survival of an aircraft when operating in a man-made hostile environment.

Vulnerability

The characteristics of a system that cause it to suffer a finite level of degradation in performing its mission as a result of having been subjected to a certain level of threat mechanisms in a man-made hostile environment.

*Vulnerability Reduction

Any technique that enhances the aircraft design in a manner that reduces the aircraft's susceptibility to damage when subjected to threat mechanisms.

*Threats

Those elements of a man-made environment designed to reduce the ability of an aircraft to perform mission-related functions by inflicting damaging effects, forcing undesirable maneuvers or degrading systems effectiveness.

*Threat Mechanisms

Mechanisms, embodied in or employed as a threat, which are designed to damage (i.e., to degrade the functioning of or to destroy) a target component or the target itself.

Aircraft Survivability Assessment

Systematic description, delineation, quantification, and statistical characterization of the survivability of an aircraft in encounters with hostile defenses.

Aircraft Vulnerability Assessment

Systematic description, delineation, and quantification of the vulnerability of an aircraft when subjected to threat mechanisms.

*Aircraft Probability of Survival

The probability that an aircraft will survive a defined damage level in specified threat engagements.

Aircraft Probability of Kill

The probability that an aircraft will not survive a defined damage level in specified threat engagements.

*System Response

The reactions of a system, including crew station, structure, and subsystems, when a threat is detected or the system is subjected to a threat mechanism.

*Target Lethality Criteria

Quantitative and qualitative data that collectively define (1) the susceptibility of the target to damage processes and (2) the resultant responses of the target given that threat-induced damage occurs.

*Damage/Kill Criteria

Quantitative and qualitative data that relate target response to damage processes (penetration, blast effects, etc.) in terms of mission performance factors.

*Hardening

That type of vulnerability reduction effected by interposing less essential components between critical components and the damage mechanisms, by eliminating critical components, or by the use of materials having improved characteristics.

*Survivability Enhancement Tradeoffs

The process of examining and quantifying both the survival benefits and the penalties associated with alternative survavability enhancement techniques of aircraft and subsystems; the objective of this tradeoff process is to derive the insights necessary to select the optimal configuration or utilization for defined mission roles.

*Reduction of Detection

The use of techniques that reduce the target aircraft signatures (i.e., infrared, radar, visual, etc.) that are used for guidance by a man-made threat mechanism.

Passive Countermeasures

Those techniques related to reduction of detection which differ from active countermeasures in the sense that no counter-electromagnetic spectrum is generated for defense.

Susceptibility

The combined characteristics of all the factors that determine the probability of hit of an aircraft component, subsystem, or system by a given threat mechanism.

Threat Negation

To render a threat ineffective through the use of countermeasures, tactics, or suppressive fire.

4. GENERAL REQUIREMENTS

4.1 Categorizátion of the S/V Discipline. The total nonnuclear aircraft survivability/vulnerability discipline (hereafter referred to as the S/V discipline) spans a large number of activities and elements such as: analysis of the inherent capability of enemy threats, the effectiveness of those threats in particular environments, analysis of inherent aircraft damage susceptibility, the response of materials to threat impact,

the development of analytical assessment procedures, analysis of combat data, the development of vulnerability reduction techniques, aircraft tradeoffs that include and interface with other disciplines such as maintainability, reliability, etc. The S/V discipline, therefore, is multidimensional; however, these many activities can be grouped or categorized into "topical fields", as illustrated in Table I. Furthermore, each topical field can be partitioned into subfields which group the activities and elements of each topical field. This subfield categorization is shown in Figures 1 through 6 for each of the topical fields in Table I, respectively.

TABLE I. S/V Topical Fields

Topical Field (Fig. No.)	Associated Activities/Elements
Threats (1)	Threat analysis, threat characteristics data, threat imherent lethality assessment
Assessment Methodology (2)	Computational methods and measures of aircraft survivability/vulnerability
System Response (3)	System/subsystem response to threat impact; lethal criteria data; kill levels; kill mechanisms
Survivability Enhancement (4)	Vulnerability reduction; hardening; self defense; electronic countermeasures; reduction of detection
Survivability Enhancement Tradeoffs (5)	Benefits and penalties from survivability enhancement; tradeoffs
S/V Test and Combat Data (6)	Test data, experimental methods; combat data analysis

The terms shown in the topical field and subfield organization of Figures 1 through 6 essentially define the activities and elements of the S/V discipline. [Reference to a topical field (e.g., survivability enhancement) represents an activity; reference to a first-level subfield (e.g., aircraft design enhancement) represents the approach selected to accomplish this activity; and references to lower-level subfields (e.g., vulnerability reduction, hardening and component relocation) provide increasingly detailed disclosures of the S/V activities initiated to achieve survivability enhancement.] In addition to these topical field and subfield terms, there is a large number of terms that are used to describe

specific data, methodology, measures, and so forth. This body of specific terms is integrated into the topical field and subfield structure at the lowest level of subfield categorization. These terms, then, are specific descriptors of each S/V activity.

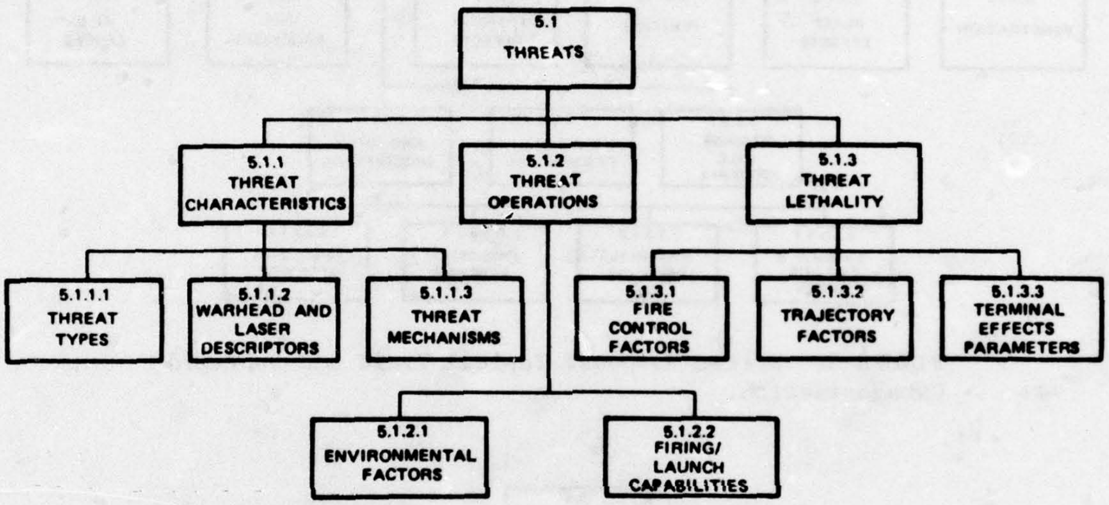


FIGURE 1. Threats Topical Field and Subfield Categorization.

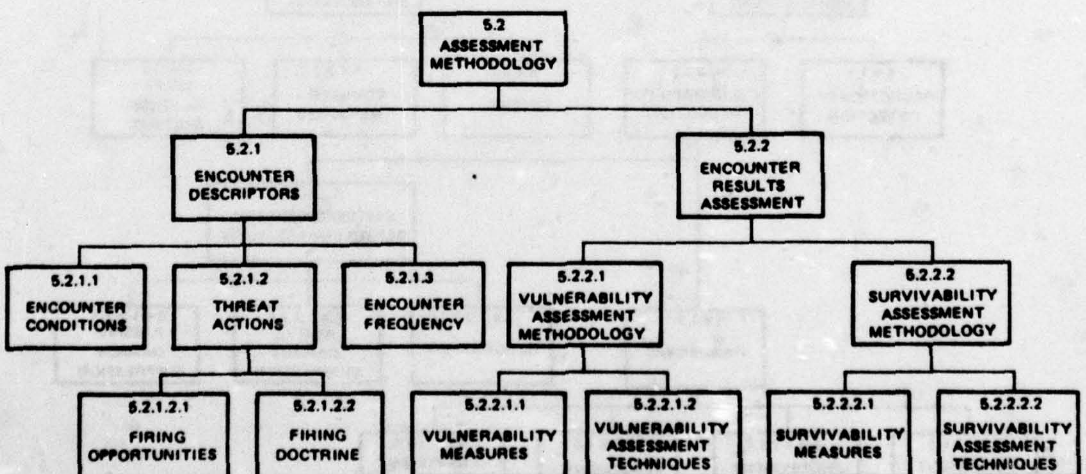


FIGURE 2. Assessment Methodology Topical Field and Subfield Categorization.

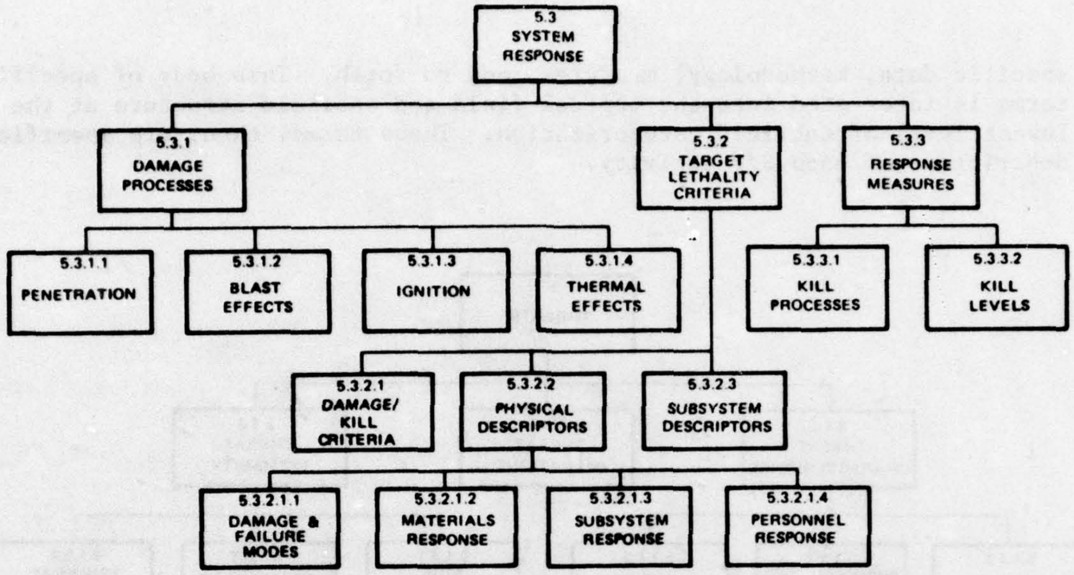


FIGURE 3. System Response Topical Field and Subfield Categorization.

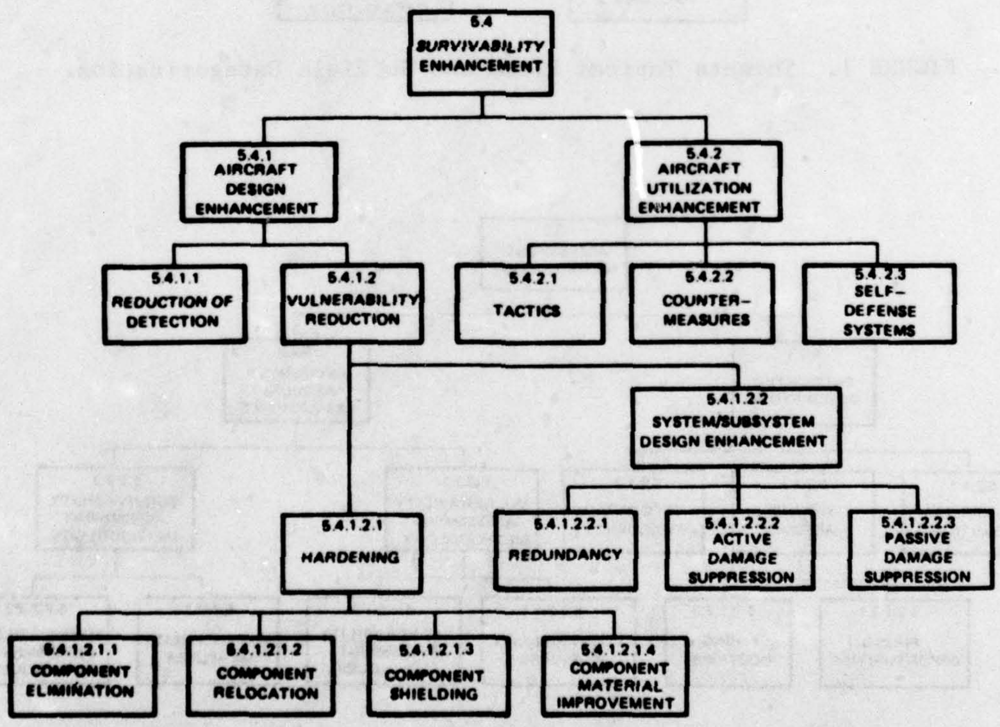


FIGURE 4. Survivability Enhancement Topical Field and Subfield Categorization.

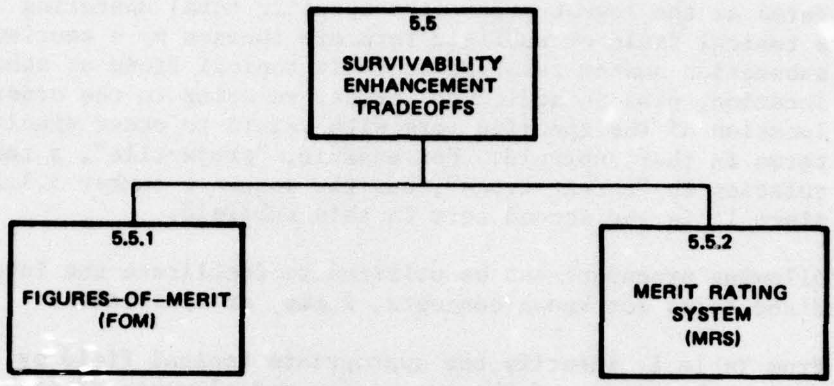


FIGURE 5. Survivability Enhancement Tradeoffs Topical Field and Subfield Categorization.

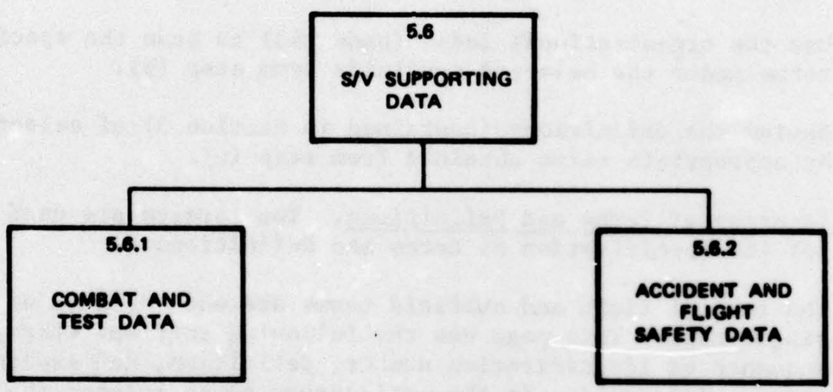


FIGURE 6. S/V Supporting Data Topical Field and Subfield Categorization.

4.2 Location of Terms and Definitions. An alphabetical index is provided (page 151) to facilitate the location of the definition for each of the terms given in this document. Each term is also indexed by a sequence number that refers to the location of that term as contained in Section 5. Two distinctions are made:

(a) Topical field and subfield terms are indexed by a section or subsection number. For example, the term "threats" is a topical field and has the sequence number 5.1; the term "threat lethality" is a subfield of "threats" and has the sequence number 5.1.3.

(b) Terms at the lowest order (the specific term) appearing under a topical field or subfield term are indexed by a section or subsection number relating to their topical field or subfield location, plus an additional number relating to the ordered location of the specific term with regard to other specific terms in that subfield. For example, "projectile", a term relating to "threat types", has the sequence number 5.1.1.1-2 since it is the second term in this subfield.

The following procedure can be utilized to facilitate the location of standardized terms for known concepts, items, or activities:

(a) From Table I, identify the appropriate topical field by comparing the nature of the activities and elements of each topical field to the known concept.

(b) Examine the respective figure (Figures 1 through 6) to locate the appropriate subfield (specific terms in the case of Figure 6) under the topical field selected in step (a).

(c) Use the organizational index (page 143) to scan the specific terms under the selected subfields from step (b).

(d) Review the definitions (contained in Section 5) of selected or appropriate terms obtained from step (c).

4.3 Specification of Terms and Definitions. Two formats are used in Section 5 for the specification of terms and definitions:

(a) The topical field and subfield terms are each defined on a single page. This page has the following entries: term, sequence or identification number, definition, and explanatory notes. Information in the explanatory notes relates the term to the topical field organization, provides further subfield categorization, and descriptive comments to eliminate confusion with other terms, and delineates standardized usage for the term.

(b) The main body of terms, indexed under the lowest-order subfield, are entered consecutively in a standard dictionary format. The terms, however, are arranged in a meaningful fashion to preserve appropriate comparisons. The definition, sequence or identification number, and explanatory notes are compiled in a narrative manner.

4.4 Use of the Standardized Terms and Definitions. The terms contained in this document should not be used in applications that perturb or change the standardized definitions. The terms do not constitute the total vernacular of the S/V discipline; rather they represent a key subset of the

total vernacular of terms. The terms were selected because (1) they form the necessary framework for categorizing the activities and elements of the S/V discipline, (2) they are representative descriptors of specific activities and elements of the S/V discipline, and (3) they resolve specific problems. There are a number of terms which can be used synonomously with these standardized terms. These "related but non-standardized terms" are necessary to allow freedom of expression and the unrestricted growth of the S/V discipline. However, persons who utilize S/V concepts are cautioned that the terms in this document are the only known standardized terms. Hence, it is significant that new or related terms must be carefully and fully defined for each application.

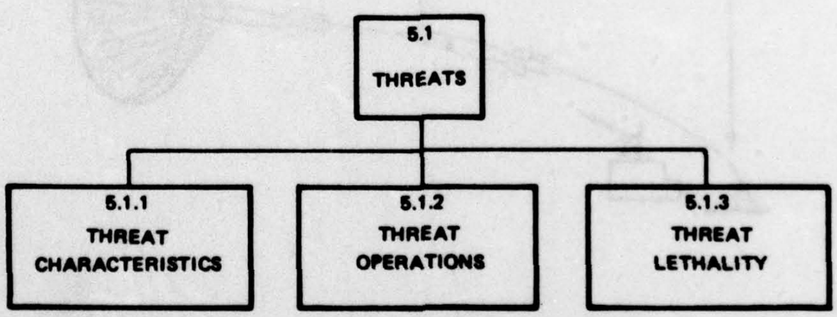
5. DETAILED REQUIREMENTS

The definitions of the S/V terms are contained in this section; these definitions have been grouped in topical fields with tab dividers included for ease of access. The topical fields are lined with a heavy, dotted black line and the associated subfields are lined with a finer black line.

5.1 Topical Field Term: Threats

Definition: Those elements of a man-made environment designed to reduce the ability of an aircraft to perform mission-related functions by inflicting damaging effects, forcing undesirable maneuvers or degrading systems effectiveness.

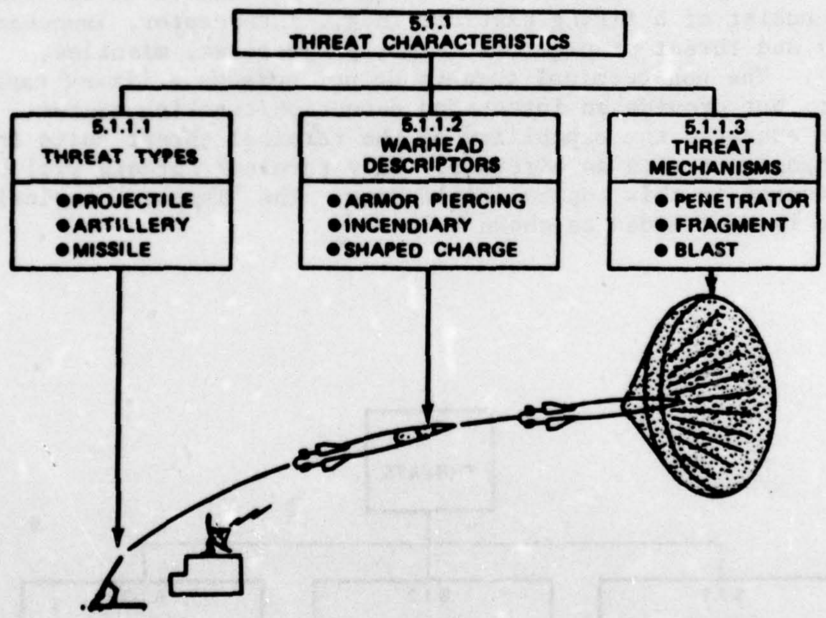
Explanatory Notes: A hostile environment can be made up of numerous threat elements, each having a distinct set of characteristics and capabilities. The "threats" topical field contains terms which are used to describe: (1) the threat elements, (2) threat operations, and (3) threat lethality. These terms and the associated data do not reflect any interaction between the threat elements and the aircraft or target. Rather, these descriptors relate to the inherent or possessed capabilities of threats. In general, threat units can be grouped into two types - terminal and non-terminal. Terminal threat units have the capability to deliver damaging effects on an aircraft, and consist of a firing platform (e.g., interceptor, launcher, etc.) and threat propagators (e.g., projectiles, missiles, etc.). The non-terminal threats do not possess a firing capability but provide an integrated detection/tracking system, which enhances the capability of the terminal threat units in an engagement with an aircraft. Only terminal threats will be considered in this Topical Field Term. The "Threats" topical field is subdivided as shown below.



5.1.1 Subfield Term: Threat Characteristics

Definition: The classification of threats according to generic characteristics - type, warhead, and associated threat mechanisms.

Explanatory Notes: The distinction between the three major subfields of "Threat Characteristics" and example terms for each subfield are shown below. Note that only generic terms are used; specific designations (e.g., SA-2) are not defined entries.

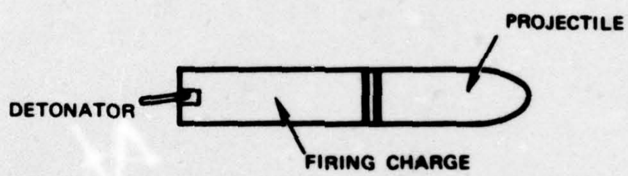


5.1.1.1 Subfield Term: Threat Types

Definition: A general characterization of the threat unit in terms of firing platform and site type, the entity containing the threat mechanism, and similar descriptors.

5.1.1.1-1 Conventional Weapon - Any weapon whose damage mechanisms do not include nuclear effects, biological agents, or chemical agents other than incendiary and tracer materials. "Conventional weapon" is used to represent all classes and types of nonnuclear threats such as small arms, anti-aircraft artillery, surface-to-air and air-to-air missiles with blast or fragmenting warheads, and high-energy lasers. Threat mechanisms included consist of blast, penetrators, fragments, incendiaries, and power (laser effects).

5.1.1.1-2 Projectile - An object propelled by an applied exterior force and continuing in motion by virtue of its own inertia, as a bullet, bomb, shell, or grenade. "Projectile" is generally used to represent the device containing the warhead and threat mechanism associated with small arms and anti-aircraft artillery. A sketch of a projectile is shown below.

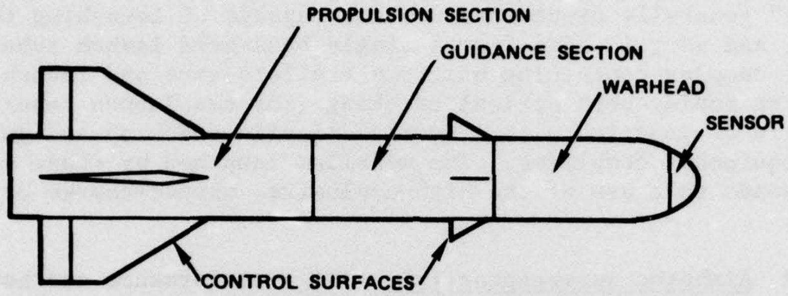


5.1.1.1-3 Small Arms - Weapons that fire projectiles up to and including 14.5mm. "Small arms" is generally used to represent enemy weapons with calibers of 7.62mm, 12.7mm, and 14.5mm. These weapons employ visual or optical tracking, and they are fabricated in differing configurations (i.e., single barrel, two barrel, four barrel, etc.). The projectiles fired by these weapons are either of the ball, armor-piercing, or armor-piercing-incendiary type.

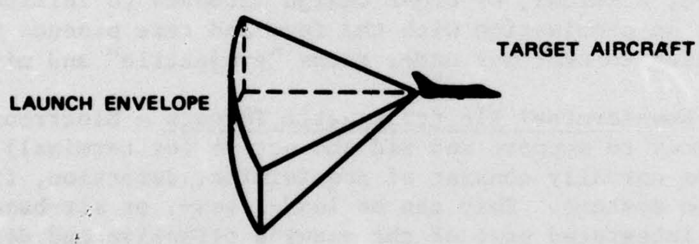
5.1.1.1-4 Anti-aircraft Artillery (AAA) - Gun-fired projectiles greater than 20mm in size that are designed to operate against airborne targets. They are generally of calibers 23mm, 30mm, 37mm, 57mm, 85mm, and 100mm, although there are some older types with calibers greater than 100mm. The projectiles are usually high-explosive but may be armor-piercing. Either may contain an incendiary and/or tracer type material. The weapons that fire these projectiles may be ground or sea-based, employ either optical or radar tracking, or both, and be fabricated in differing configurations (i.e., single barrel, two barrel, four barrel, etc.).

5.1.1.1-5 Missile - An aerospace vehicle, with varying guidance capabilities, which is self-propelled through space for the purpose of inflicting damage on a designated target. These vehicles are fabricated for air-to-air, surface-to-air, air-to-surface, or surface-to-surface roles. They contain a propulsion system, warhead section, guidance system and sensor (or antennae for receiving remote guidance signals), and control surfaces. The guidance capabilities of the different missiles

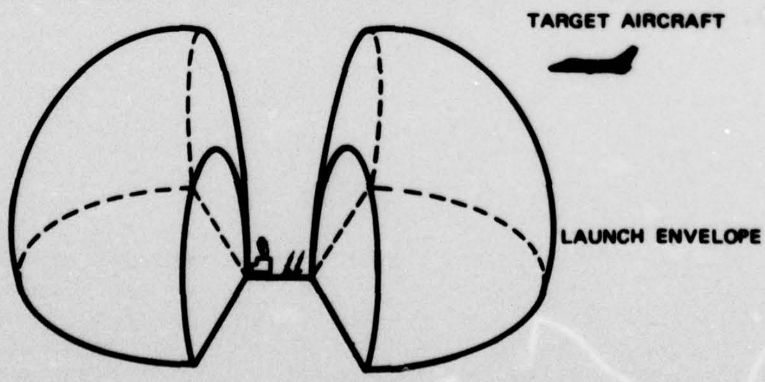
vary from self-guided to complete dependence on the launch equipment for guidance signals. A sketch of a missile is shown below.



5.1.1.1-6 Air-to-Air Missile (AAM) - Missiles launched from interceptor aircraft for the purpose of inflicting damage on an airborne target. These missiles have varying guidance and propulsion capabilities which dictate the launch envelopes relative to the airborne target and their susceptibility to countermeasures or any other means of threat negation. An example of an AAM launch envelope is sketched below. (See subfield 5.1.2.2 for the definition of "launch envelope".)



5.1.1.1-7 Surface-to-Air Missile (SAM) - Missiles launched from ground-based (or sea-based) equipment for the purpose of inflicting damage on an airborne target. These missiles have varying guidance and propulsion capabilities which dictate their launch envelopes relative to the target and their susceptibility to countermeasures or any other means of threat negation. An example of a SAM launch envelope is sketched below.



5.1.1.1-8 SAM Launch and Guidance Equipment - Equipment which is used to launch and guide SAMs to an intercept point. "SAM launch and guidance equipment" generally represents systems capable of launching the different SAMs, and vary in size from a single hand-held launch tube to a semi-permanent complex containing numerous trailers/vans and launch units. The systems employ both optical tracking (for the launch tube) and radar tracking in conjunction with a special missile tracking and guidance mode for the equipment complexes. The missiles launched by these systems contain warheads that are of the high-explosive, shaped-charge or continuous-rod type.

5.1.1.1-9 Airborne Interceptor (AI) - High-performance and normally highly maneuverable aircraft designed to engage and destroy aircraft targets. Weapon systems consist of air-to-air cannon, air-to-air missiles, and associated equipments for the purpose of identifying and tracking aircraft and firing weapons. These interceptors may be limited to visual flight conditions (i.e., a day fighter) or may be configured to operate under all weather conditions (i.e., an all-weather interceptor).

5.1.1.1-10 Warhead - The part of a projectile or missile which constitutes the explosive, chemical, or other charge intended to inflict damage. These constituents in combination with the fuze and case produce the threat mechanisms. (Refer to sketches under terms "projectile" and missile".)

5.1.1.1-11 Non-terminal Electromagnetic Threats - Electronic systems used by enemy forces to support and aid the active (or terminal) threat units. These systems normally consist of acquisition, detection, tracking, and communication systems. They can be land-, sea-, or air-based, and are normally an integrated part of the enemy's offensive and defensive forces. Their purpose is to supply appropriate position, velocity, heading, etc., information to the terminal or active threat units.

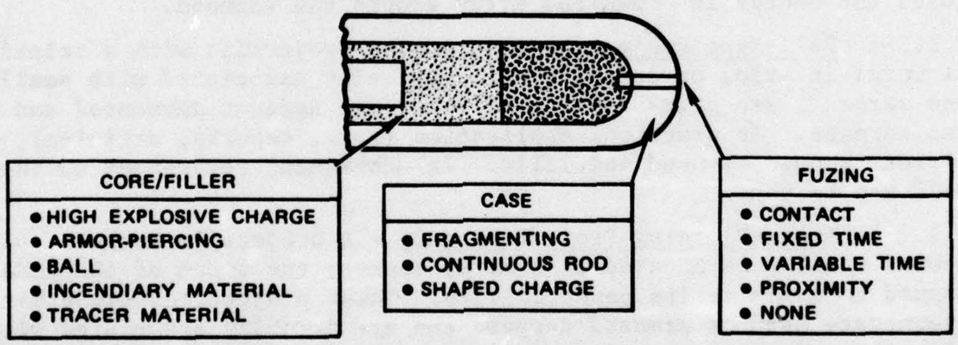
5.1.1.1-12 High Energy Laser (HEL) - A weapons system which produces a collimated beam of electromagnetic radiation with an intensity sufficient to melt or thermally degrade a portion of the target. It may also be used to damage electromagnetic subsystems of the target by overloading (in-band kill).

5.1.1.2 Subfield Term: Warhead (or Laser) Descriptors

Definition: Descriptors characterizing the basic configuration and ingredients of the warhead and the activation methods/ devices which collectively generate the threat mechanisms.

Explanatory Notes: Typical warhead elements are shown below. These elements can be combined to obtain a specific type of projectile/missile (e.g., armor-piercing projectile, armor-piercing incendiary projectiles, high-explosive projectile) that ultimately results in the generation of threat mechanisms. Some terms frequently used in this section to describe warheads, such as penetrator, fragment, tracer, and incendiary, are defined in Section 5.1.1.3 (Threat Mechanisms).

PROJECTILE/MISSILE WARHEAD



5.1.1.2-1 Warhead Fuze - That element of a warhead which initiates the detonation of the explosive charge. Proximity fuzing (i.e., initiation within a predetermined distance to a target) is normally used for missile warheads and some large AAA projectiles. Contact fuzing (i.e., initiation on impact) is normally used for AAA projectile and may be delayed or instantaneous.

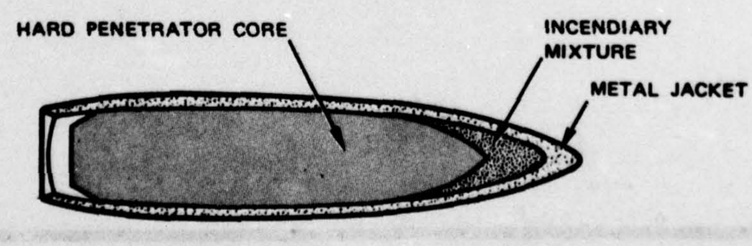
5.1.1.2-2 High-Explosive Charge - Any powerful, nonatomic explosive material characterized by extremely rapid detonation and a powerful disruptive or shattering effect. The high-explosive charge is used to generate high-speed fragments as well as to develop potentially damaging blast effects on the target. In practical application (e.g., reports, articles), the full term should be used initially. In subsequent references to the term, "high explosive" or "charge" may be used. "High-explosive charge" is normally used to modify (and describe) specific warhead types such as high-explosive incendiary, high-explosive incendiary tracer, etc.

5.1.1.2-3 Shaped Charge - A high-explosive charge that is shaped in conjunction with the casing so that energy created by detonation is focused in a desired direction. The focused energy creates high fragment velocities. In general, there are two types of shaped charges - spherical, which focuses energy to a selected point in the warhead, and linear, which focuses the energy in a desired array around the warhead.

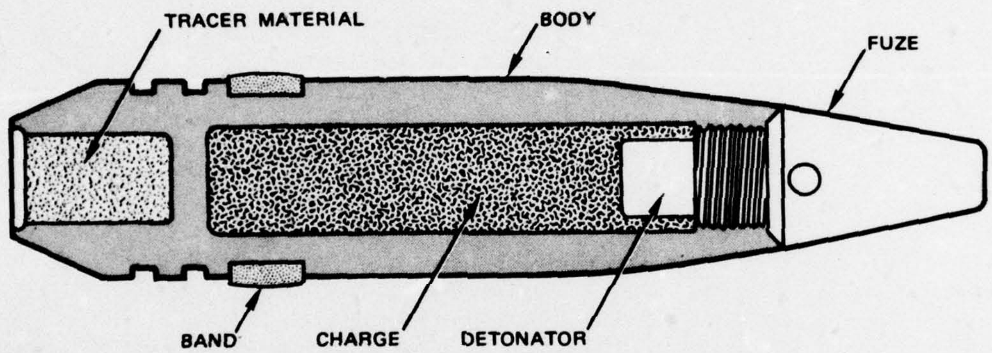
5.1.1.2-4 Ball-Type Projectile - A passive projectile with a relatively soft metal interior or core which is typically associated with small arms. These warheads are primarily intended for use against personnel and unarmored targets. In practical application (e.g., reports, articles), the full term should by used initially. In subsequent references to the term "ball" may be used.

5.1.1.2-5 Armor-Piercing Projectile (AP) - A projectile composed of a hardened steel core encased in a metal jacket; the shape of the core is designed to maximize its penetrability. These projectiles are utilized to penetrate hard or armored targets and are normally associated with small arms and anti-aircraft artillery.

5.1.1.2-6 Armor-Piercing Incendiary Projectile (AP-I) - A projectile utilizing a hardened steel core with an incendiary mix in the nose, all of which is encased in a metal jacket. These projectiles are utilized to penetrate hard or armored targets and to ignite fires or explosions with the incendiary materials. These projectiles are normally associated with small arms and anti-aircraft artillery. A sketch of a typical armor-piercing incendiary projectile is shown below.



5.1.1.2-7 High-Explosive Projectile (HE) - A projectile composed of a hollow steel body containing a high-explosive filler. Such projectiles normally consist of a steel outer shell with an internal explosive charge detonated by a fuze in the nose. Fuzing may be contact, fixed time (FT), variable time (VT), or proximity (PROX). There are two types of contact fuzes for HE projectiles: delay and super quick. Delay-fuzed HE projectiles are designed to penetrate a target and explode internally to cause the maximum damage from the blast effects. Super quick fuzes will cause external detonation. Externally detonated HE projectiles rely on penetration of the target from fragments of the exploding projectile body. Fragment size and population depend on the specific projectile. HE projectiles are normally associated with anti-aircraft artillery (AAA). A typical high-explosive projectile is sketched below.



5.1.1.2-8 High-Explosive Incendiary Projectile (HE-I) - A projectile composed of a hollow steel body containing a high-explosive filler and an incendiary mixture. Such projectiles normally consist of a steel outer shell with an internal explosive charge and incendiary mixture detonated by a contact fuze, either delay or super quick, on the nose. Delay-fuzed HE-I projectiles penetrate a target and explode internally to cause damage from blast effects as well as with fragments and burning incendiary. Fragment size and population depend on the specific projectile. HE-I projectiles are normally associated with anti-aircraft artillery (AAA).

5.1.1.2-9 High-Explosive Incendiary Tracer Projectile (HE-I-T) - A projectile composed of a hollow steel body containing high-explosive, incendiary, and tracer materials. The incendiary material is included to provide an ignition source on impact, and the tracer material is added to provide a visual image of the projectile's flight path.

5.1.1.2-10 Fragmenting Case - A casing designed to break into fragments upon detonation. The fragments may be of a uniform size calculated to optimize the effectiveness of the weapon against a particular type of target. The desired fragment dimensions can be obtained by scoring the case or by wrapping it with wire.

5.1.1.2-11 Continuous Rod Warhead - A warhead which contains a bundle of rods welded together at alternate ends. Upon detonation of the explosive load the rod bundle expands at right angles to the missile to a maximum radius and then breaks apart. This steel ring can knife through skin and skeletal members of aircraft structure.

5.1.1.2-12 Delivered Energy Distribution (DED) - The distribution of energy/area delivered to a target (i.e., through a plane normal to the incident laser beam at the target location). The DED includes both a description of the energy pile (time integral of the intensity that has passed through each point of the incident plane) and a probability distribution of energy piles about the desired aimpoint.

5.1.1.3 Subfield Term: Threat Mechanisms

Definition: Mechanisms, embodied in or employed as a threat, which are designed to damage (i.e., to degrade the functioning of or to destroy) a target component or the target itself.

Explanatory Notes: Note that "threat mechanism" refers to that which produces an effect (e.g., penetrator), whereas "damage process" (see Section 5.3.1) refers to the process whereby the effect is produced (e.g., penetration). The table below clarifies the content of this term as distinguished from terms and meanings with which it might be confused.

SUBFIELD	KEY FACTORS OF DEFINITION	EXAMPLE TERMS
5.1.1.3 Threat Mechanisms	<u>Nature</u> of the Warhead Output	o Blast o Penetrator o Fragment o Incendiary o Electromagnetic Flux
5.1.3.3 Terminal Effects Parameters	<u>Intensity</u> of the Threat Mechanisms Output	o Projectile Caliber o Equivalent Weight of TNT o Incendiary Flash Duration o Fragment Density
5.3.1 Damage Processes	<u>Interactions</u> Between Threat Mechanisms and Target	o Blast Effects ✓ Blast Loading o Ignition ✓ Explosion o Penetration ✓ Ballistic Impact o Thermal Effects ✓ Impulse Loading

5.1.1.3-1 Blast - The brief and rapid movement of air or other fluid away from a center of outward pressure, as in an explosion; the pressure accompanying this movement. Blast is a threat mechanism associated with high-explosive warheads such as contained on anti-aircraft artillery (20mm and larger) or surface-to-air and air-to-air missiles. Depending on the warhead and fuzing, the blast may be external or internal to the target.

5.1.1.3-2 Penetrator - The core or that part of an armor-piercing projectile designed to penetrate to the interior of a target. Penetrators are threat mechanisms associated with small arms and anti-aircraft artillery.

5.1.1.3-3 Fragment - Metal particles of varying weight, size, and velocity that are produced by ballistic impact and the detonation of projectiles and missile warheads. Fragments are threat mechanisms associated with anti-aircraft artillery and surface-to-air and air-to-air missile warheads. Depending on the warhead fuzing, initial fragment impact may be external (proximity fuzed) or internal (contact-fuzed) to the aircraft. In addition to being directly produced by the detonation of a warhead, fragments can be the result of a ballistic impact on a target. In this case, fragments are a by-product of material response such as spall.

5.1.1.3-4 Tracer - An active bright-burning material typically used with a projectile to make the flight of the projectile visible both by day and by night. Tracers are primarily used as an aiming aid with small arms, AAA, and airborne gun systems. However, tracers do have the capability to initiate combustion and, hence, are categorized as a threat mechanism. A typical tracer material installation is shown in the explanatory notes under "High-Explosive Projectile".

5.1.1.3-5 Incendiary - Any chemical agent designed to cause combustion; used especially as a filling for certain bombs, shells, projectiles, or the like. A typical application of an incendiary material is in a small arms or contact-fuzed anti-aircraft artillery (AAA) projectile. For the small-arms projectile, for example, a thermally active incendiary filler is used with a passive core, either ball or armor-piercing material. The incendiary is located in front of the passive core and is initiated upon contact with the target. (See sketch, paragraph 5.1.1.2-6.)

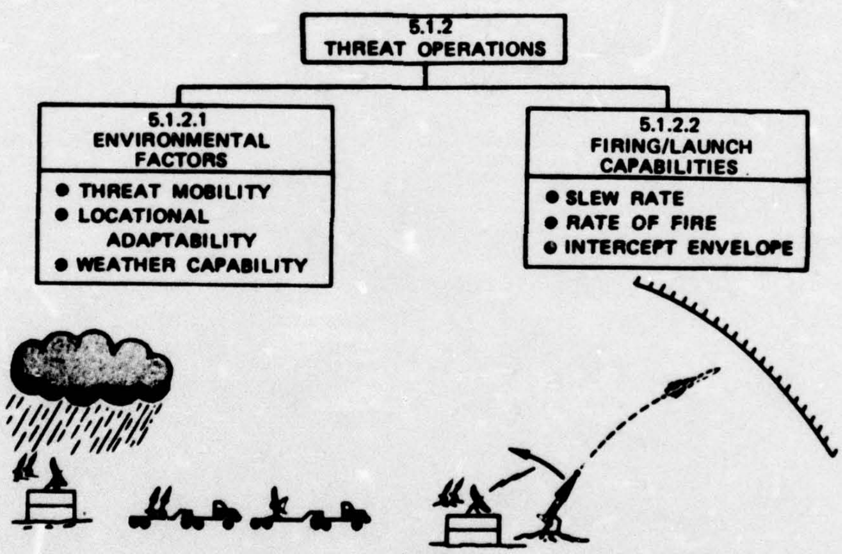
5.1.1.3-6 Electromagnetic Flux - Electromagnetic energy per unit time or power passing through a surface.

5.1.1.3-7 Power - The energy per unit time which a High Energy Laser Weapon System (HELWS) is capable of delivering.

5.1.2 Subfield Term: Threat Operations

Definition: Those inherent capabilities and environmental factors which relate to the ability of a threat to perform its basic firing/launch functions.

Explanatory Notes: "Threat operations" has been subdivided into "environmental factors" and "firing/launch capabilities", which contain several terms each, as indicated by the schematic below.



5.1.2.1 Subfield Term: Environmental Factors

Definition: Those factors which relate to the inherent capability of a threat to adapt to and function in various operational environments.

Explanatory Notes: "Environmental factors" refers to those conditions, both physical and atmospheric, which tend to degrade the capability of the threat when it is operating in a combat environment.

5.1.2.1-1 Threat Mobility - The ease with which a threat can be moved. Factors considered are the effort required for disassembling, loading, transporting, and setting up a new location so that effective firing or launching can be achieved. The measures of mobility are operational time at one location or downtime required in moving from one operating site to another.

5.1.2.1-2 Locational Adaptability - The ability of a threat to adapt to the sites at which its operation is desired in a combat environment. Factors which must be considered in site selection for threats are area required, smoothness of terrain, access to road/highway, class of highway required for transporting threat, etc.

5.1.2.1-3 Weather Capability - The ability of a threat to track and deliver the threat mechanism to a target during specified variations in visibility, cloud cover, or light conditions. Generic measures of tracking capability include: (1) clear day - ability to maintain track under daylight conditions with no intervening clouds and required visibility; (2) clear night - ability to maintain track with no cloud or visibility constraints, but with reduced light level (i.e., half moon, quarter moon, etc.); (3) hazy - a qualifier for day or night to indicate an increased amount of particulate matter in the air (i.e., smoke, dust, etc.) which will degrade the effectiveness of a HELWS; and (4) all weather - ability to maintain track with extremely low light levels, complete cloud cover, or minimal visibility.

5.1.2.2 Subfield Term: Firing/Launch Capabilities

Definition: Physical characteristics and limitations which describe the basic operational capabilities of a threat system in a favorable environment.

Explanatory Notes: "Firing/Launch Capabilities" represents the inherent capabilities of the threat without regard to a specific encounter situation with an aircraft. The table below clarifies the content of this group of terms with respect to similar terms in other subfields.

SUBFIELD	KEY FACTORS OF DEFINITION	EXAMPLE TERMS
5.1.2.2 Firing/Launch Capabilities	Inherent Threat Firing/Launch Capability	o Initial Reaction Time o Firing/Launch Envelope o Slew Rate o Rate of Fire o Threat Firing Modes
5.2.1.1 Encounter Conditions	Encounter Characteristics	o Open-Fire Range o Target Offset o Target Angle Off
5.2.1.2.1 Firing Opportunities	Logical Use of Weapon in an Encounter	o Allowable Firing Sector o Unmask Range o Number of Rounds Fired
5.2.1.2.2 Firing Doctrine	Use of Firing Opportunities	o Barrage Fire o Fire-While-Track o Shoot-Look-Shoot

5.1.2.2-1 Initial Reaction Time - The interval which elapses between the time a threat is made aware of a need to be fully operational and the time the threat is ready to begin its normal operational mode against target aircraft. The functions, which can be accomplished in parallel during this time interval, consist of getting personnel in "combat ready" positions and transferring the equipment from a standby or alert status to a fully operational status.

5.1.2.2-2 Firing/Launch Envelope - A locus of points which represents the position of an aircraft target when a projectile/missile can be fired/launched with the expectation of achieving an intercept on the aircraft. When considering ground-based (or sea-based) threats, the launch envelope is generally depicted relative to the location of the threat. Conversely, the launch envelope is normally shown relative to the target aircraft in the consideration of airborne threats. This envelope considers the tracking time required before a launch can feasibly be accomplished. (Refer to sketches under terms "air-to-air missile" and "surface-to-air missile".)

5.1.2.2-3 Intercept Envelope - A locus of points within the launch envelope which defines the maximum range at which an intercept could be made by a projectile or missile under operational conditions.

5.1.2.2-4 Maximum Effective Range - The maximum distance which a projectile or missile could be propelled by the applied force and still arrive with sufficient residual velocity to cause damage to the target. This also refers to the maximum distance at which the delivered energy density of a HEL beam is sufficient to cause damage to the target after an appropriate time interval is considered. This measure does not consider the effects of such operation considerations as tracking time, projectile/missile time of flight, probability of hit, etc.

5.1.2.2-5 Muzzle Velocity - The velocity of the projectile with respect to the muzzle at the instant the projectile leaves the weapon. This velocity is a function of the projectile weight, firing charge of the projectile, barrel characteristics, etc. The weapon can be either small arms or AAA.

5.1.2.2-6 Maximum Slew Rate - The maximum angular velocity - in both azimuth and elevation - at which the firing/launch carriage of the threat can be rotated in order to begin tracking and engaging a target that was in a different sector of the sky than the weapon had been initially pointing. The parameters which determine these velocities include mass or weight of the equipment to be rotated, the electrical/mechanical/hydraulic power available to rotate the equipment, etc.

5.1.2.2-7 Maximum Tracking Rate - Maximum rates in azimuth or in elevation that the firing or launch mechanism can be rotated while position vs time is measured and used in the prediction of target future position. (Slewing rate denotes "clutch disengaged" or "uncoupled" rotation of firing mechanism.)

5.1.2.2-8 Rate of Fire - The number of projectiles per unit time that a threat is capable of firing. This term is primarily used as a measure for small arms and AAA. Launch rate is a similar term which is used in connection with number of missiles per unit time which can be launched by a SAM site.

5.1.2.2-9 Threat Firing Modes - A set of operational usage options possessed by a threat which are attributable to the associated equipment (i.e., fire control system, sensors, etc.). The different modes are normally defined in terms of the sensors used for obtaining the ranging and tracking information required to predict lead angle information. Examples are: optical/optical (i.e., optical ranging and optical tracking), radar/radar (i.e., radar ranging and radar tracking), radar/optical (i.e., radar ranging and optical tracking), etc.

5.1.2.2-10 Lock-on Boundary - Area projected on the ground plane wherein the missile seeker can automatically track (lock-on) to the target's radar or infrared signature.

5.1.2.2-11 Kinematic Boundary - Area projected on the ground plane wherein the missile reaches flight speed and can maneuver, and its warhead is armed (inner Kinematic boundary) or the area projected on the ground within which an intercept can be made due to limitations on missile on board propellant (maximum range capability, outer Kinematic boundary).

5.1.2.2-12 Dead Zone - That area in the immediate vicinity of the gun or missile site wherein targets cannot be engaged due to such things as arming distances, flight speed for missile maneuvering, high angular rates of the target for guns, etc.

5.1.2.2-13 Detection Time - Time from break mask (unmask) until presence of a target is discerned.

5.1.2.2-14 Acquisition Time - Time from detection until some sighting or tracking device has been brought to bear.

5.1.2.2-15 Identification Time - In air defense missile sites, the time from acquisition (track) until the target responds to IFF interrogation, or until several seconds have elapsed, indicating no response. In general, the elapsed time between acquisition and determination as to hostile, friendly, or unknown.

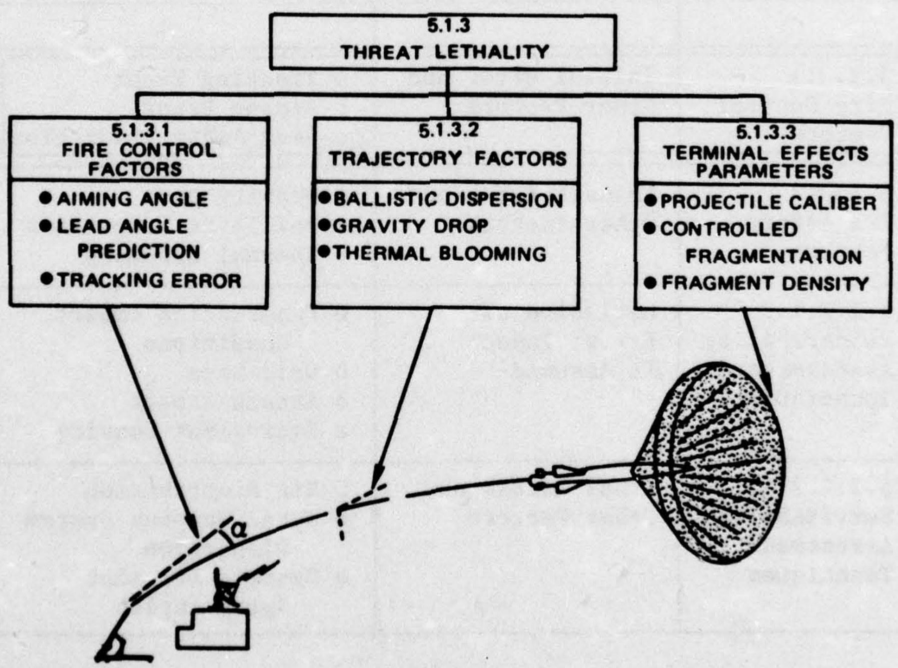
5.1.2.2-16 Engagement Time - Elapsed time during which the air-ground interaction is actively taking place. (Open fire, until break-off.)

5.1.2.2-17 Time-of-Flight - Elapsed time from missile launch until arrival in the vicinity of the target, or from the time a round or burst leaves the muzzle until it reaches the vicinity of the target.

5.1.3 Subfield Term: Threat Lethality

Definition: A delineation of those factors which relate to the fire control, trajectory, and terminal effects inherent to a threat in the process of directing, projecting, and activating threat mechanisms designed to cause damage to a target.

Explanatory Notes: The term "threat lethality" is used to refer to that collection of data which defines the threat's fire control, trajectory, and terminal effects parameters. Accordingly, "threat lethality" has been subdivided into three subfields for the categorization of terms. The subfields are depicted in the schematic below on essentially a time-sequenced basis. Example entries illustrate the general content of each of these subfields and the distinctions which are to be preserved.



5.1.3.1 Subfield Term: Fire Control Factors

Definition: Those descriptors which portray the mode, usage, and accuracy capabilities associated with the pointing, directing, firing, or launching phase of the threat sequence of operations.

Explanatory Notes: The term "fire control factors" is used to represent that collection of terms which relate to initial error sources and other factors that are incurred in the firing or launching phase of an aircraft/threat encounter. The table below clarifies the content of this group of terms with respect to terms in other subfields.

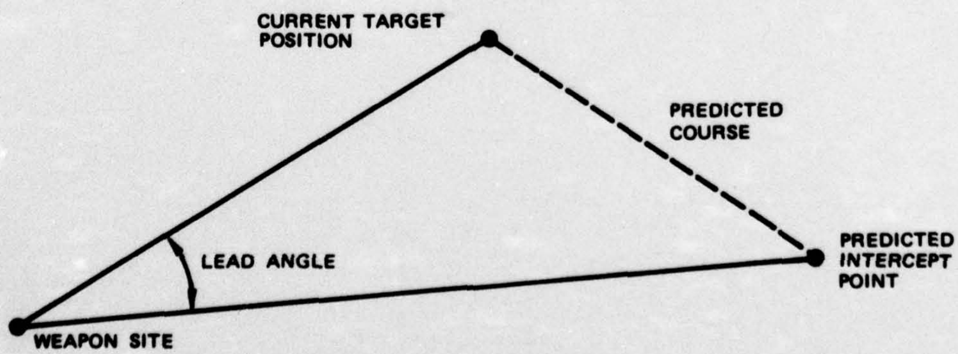
SUBFIELD	KEY FACTORS OF DEFINITION	EXAMPLE TERMS
5.1.3.1 Fire Control Factors	Initial Error and Other Factors	o Tracking Error o Aiming Error o Lead Angle Prediction
5.1.3.2 Trajectory Factors	Transit Error and Other Factors	o Gravity Drop o Ballistic Dispersion o Thermal Blooming
5.2.2.1.2 Vulnerability Assessment Techniques	Exclusive of Error; Impact Is Assumed	o Penetration Impact Conditions o Grid Size o Attack Aspect o Equivalent Density
5.2.2.2.2 Survivability Assessment Techniques	Final Errors and Other Factors	o Hit Distribution o Total Weapons System Dispersion o Dynamic Fragment Spray Angles

5.1.3.1-1 Acquisition Limit - Maximum unobscured range at which an aircraft can be acquired (or detected) by threat sensors (e.g., radar, visual, infrared).

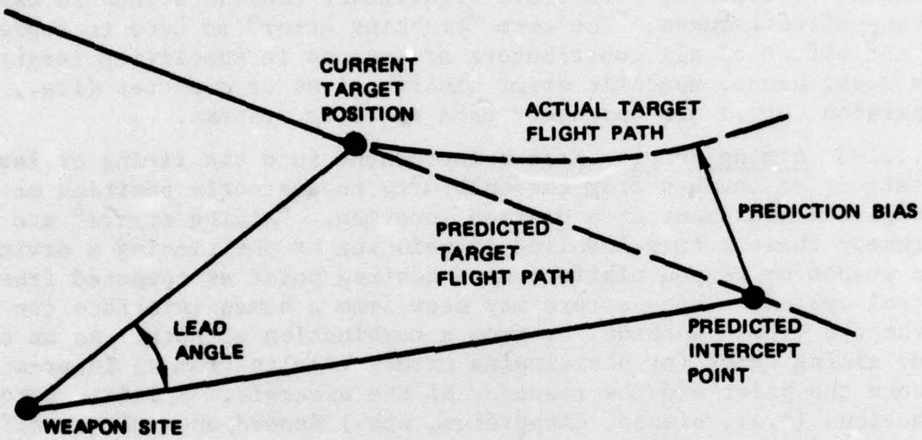
5.1.3.1-2 Tracking Error - Errors introduced into the firing or launching operations of threats by the inability of the tracking system (i.e., optical, radar, etc.) to provide an exact record of an aircraft flight path. Tracking data is utilized by the enemy defenses for many purposes - alerting appropriate threat units, establishing threat tactics, establishing lead angle information for weapon firing, etc. Therefore, the source and magnitude of tracking errors are significant considerations in assessing defense effectiveness. The term "tracking error" is used to represent the net effect of all contributors or sources in specifying target position data; hence, specific error distributions or measures (i.e., bias, dispersion, etc.) are dependent upon specific systems.

5.1.3.1-3 Aiming Error - Errors introduced into the firing or launching operations of threats from the inability to correctly position or aim the appropriate equipment at a desired location. "Aiming errors" are used to represent those errors involved in pointing or positioning a device such as a weapon or weapon platform at a desired point as computed from a fire control system. These errors may stem from a human interface (or human operator), from a machine, or from a combination of both. As an example, pilot aiming error (or positioning error) results from an inter-action between the pilot and the response of the aircraft. Specific error distributions (i.e., biases, dispersion, etc.) depend upon the specific system being considered.

5.1.3.1-4 Lead Angle Prediction - That process used to establish desired weapon positioning or aiming information. All weapons employing ballistic projectiles must be provided with some means of solving the fire control problem illustrated in the figure. From measurement of current target position and velocity, future target position must be established, weapon aim angles (e.g., azimuth and elevation) determined, and the weapon positioned and fired so that the projectiles and target will arrive at the same point simultaneously. This process is referred to as "lead angle prediction". The equipment used to measure current target position and velocity, and the logic used to predict the intercept point depends upon specific systems.



5.1.3.1-5 Prediction Bias - A bias (or miss distance) resulting from errors in the prediction of the target flight path. "Prediction bias" errors may be the result of unexpected or evasive target maneuvers (i.e., jinking) during the flight time of the projectile or from limitations inherent in the extrapolation process used to predict future target position. The "prediction bias" for any firing situation is normally defined as the minimum distance from the predicted intercept point to the target as shown in the figure.



5.1.3.1-6 Lock-on - The term used to indicate that (automatic) fine track is in progress, and that a shot can be taken.

5.1.3.1-7 Jitter - This is a combination of aiming and tracking errors produced by the system and atmospheric effects (turbulent jitter) which cause HEL beam to move about on the target surface.

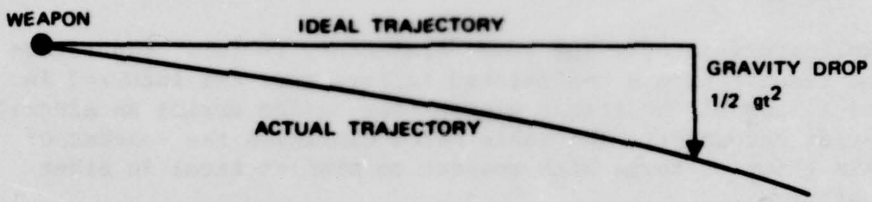
5.1.3.2 Subfield Term: Trajectory Factors

Definition: Those factors which relate to the warhead flight path or to any analogous propagation path of the threat mechanism.

Explanatory Notes: The term "trajectory factors" represents the transit errors and related factors that are incurred in the flight of the threat propagation device during an aircraft/threat encounter. The table below clarifies the content of this group of terms with respect to similar terms in other subfields.

SUBFIELD	KEY FACTORS OF DEFINITION	EXAMPLE TERMS
5.1.3.1 Fire Control Factors	Initial Error and Other Factors	o Tracking Error o Aiming Error o Lead Angle Prediction
5.1.3.2 Trajectory Factors	Transit Error and Other Factors	o Gravity Drop o Ballistic Dispersion o Thermal Blooming
5.2.2.1.2 Vulnerability Assessment Techniques	Exclusive of Error; Impact Is Assumed	o Penetration Impact Conditions o Grid Size o Attack Aspect o Equivalent Density
5.2.2.2.2 Survivability Assessment Techniques	Final Errors and Other Factors	o Hit Distribution o Total Weapons System Dispersion o Dynamic Fragment Spray Angles

5.1.3.2-1 Gravity Drop - A measure of the deviation in the flight path of a projectile attributable to gravitational force. "Gravity drop" is used to describe the displacement in the ideal trajectory of a projectile due to gravity. The gravity drop is proportional to the time of flight and has been aproximated as $1/2\ gt^2$, where g is the gravitational force and t is the time of flight.



5.1.3.2-2 Ballistic Dispersion - The scatter of impact points of projectiles about a mean point on the target under fixed firing conditions and exclusive of aiming and installation factors. "Ballistic dispersion" refers to those variations in the impact point attributable only to gun and ammunition characteristics. Causes of ballistic dispersion are weight and surface variations between projectiles, variations in muzzle velocity due to propellent weight differences, variation in burning efficiencies, etc., and variations in the aerodynamic forces. These latter factors (lift, pitching force, increased drag with yaw, etc.) result from differences in barrel exit conditions for each projectile.

5.1.3.2-3 Ballistic Coefficient - A parameter or measure which is used to represent or account for the attenuation of the velocity of a projectile or fragment in transit from the firing mechanism to the target. "Ballistic coefficients" are normally used in approximate formulations to determine average speed or times-of-flight for a projectile. For example, average projectile speed, V_p, can be obtained from

$$V_p = \frac{V_o \alpha R}{\exp(\alpha R) - 1}$$

where

V_o = muzzle velocity
R = range
α = ballistic coefficient

5.1.3.2-4 Thermal Blooming - A non-linear dispersion of electromagnetic radiation due to atmospheric-index-of-refraction changes caused by molecular absorption of the propagating energy. When electromagnetic radiation (i.e., a beam) passes through a gas, some of its radiant energy will be absorbed by the gas molecules and transformed into kinetic energy. The resultant temperature rise will force the gas particles away from the beam

until the particle density has been reduced to the proper level for that particular temperature and pressure. If the beam is non-uniform (i.e., more intense at the center than at its edges), the resultant density will be less at the center than at the edges and, hence, the atmospheric index of refraction (proportional to density) will vary across the beam. Since light rays are bent away from areas of low index of refraction, a beam dispersion results. The magnitude of this dispersive effect depends on many factors - wavelength, beam intensity, atmospheric conditions, etc. - and may not degrade all threat types.

5.1.3.2-5 <u>Atmospheric Attenuation</u> - The attenuation of electromagnetic radiation due to absorption (by gases) and scattering (by particles) by the atmosphere.

5.1.3.2-6 <u>Tumbling</u> - The rolling (propellering) about the trajectory axis, and yawing and pitching about the other two axes, which a projectile or fragment in flight experiences.

5.1.3.3 Subfield Term: Terminal Effects Parameters

Definition: Those factors which relate to the inherent capability of the warhead (or any analogous component) of a threat to generate its associated threat mechanisms.

Explanatory Notes: "Terminal effects parameters" are descriptors of the inherent ability of the threat-delivered "warhead" (in terms of intensities, velocities, distances, etc.) to generate threat mechanisms. The table below clarifies the content of this term as distinguished from terms and meanings with which it might be confused.

SUBFIELD	KEY FACTORS OF DEFINITION	EXAMPLE TERMS
5.1.1.3 Threat Mechanisms	<u>Nature</u> of the Warhead Output	o Blast o Penetrator o Fragment o Incendiary o Electromagnetic Flux
5.1.3.3 Terminal Effects Parameters	<u>Intensity</u> of the Threat Mechanisms Output	o Projectile Caliber o Equivalent Weight of TNT o Incendiary Flash Duration o Fragment Density
5.3.1 Damage Processes	<u>Interactions</u> Between Threat Mechanisms and Target	o Blast Effects ✓ Blast Loading o Ignition ✓ Explosion o Penetration ✓ Ballistic Impact o Thermal Effects ✓ Impulse Loading

5.1.3.3-1 Projectile Caliber - A standard measurement for the diameter of a projectile. This diameter can also be expressed in other linear units of measurement (i.e., millimeters, inches, etc.).

5.1.3.3-2 Equivalent Weight of TNT - The total energy of any given high-explosive shell divided by the chemical energy of one pound of TNT. With this criterion, the results of firings of bare charges of TNT can be used to estimate the damage caused by the impact of a high-explosive shell at any striking velocity.

5.1.3.3-3 Charge-to-Total-Weight Ratio - A ratio of explosive-charge weight to total-projectile weight which is normally used in emperical formulas to estimate initial fragment velocities.

5.1.3.3-4 Controlled Fragmentation - A desired combination of fragmentation pattern and mass distribution which is derived from the design of the explosive charge, casing, burning pattern, etc.

5.1.3.3-5 Incendiary Flash Duration - An interval of time over which the incendiary filler in a projectile will burn following initiation.

5.1.3.3-6 Critical Impact Velocity - A minimum striking velocity between a projectile and target at which a projectile fuze will initiate.

5.1.3.3-7 Fragment Density - The number of fragments per unit area which is normally measured in terms of the distance from the point of warhead detonation.

5.1.3.3-8 Static Fragment Spray Angles - An angular field-of-view in which fragments are emitted following the static detonation of a controlled fragmentation warhead.

5.1.3.3-9 Initial Fragment Velocity - A fragment velocity attributable solely to the detonation of the warhead.

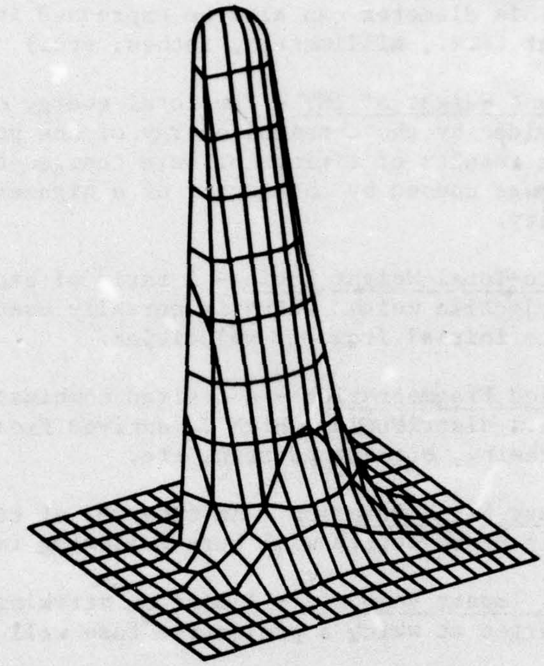
5.1.3.3-10 Total Fragment Initial Velocity - A fragment velocity attributable to both the detonation of the warhead and the velocity of the warhead at the time of detonation.

5.1.3.3-11 Coupling - The deposition of energy from an HEL beam into the target surface.

5.1.3.3-12 Flash Blinding - The brilliant illumination caused by a HEL beam interacting with the target in an area such that the personnel in the target are temporarily blinded.

5.1.3.3-13 Aimpoint - A pre-selected position on the target at which a HEL beam is to be directed.

5.1.3.3-14 Energy Pile - For a HELWS, this is the time integral of the intensity that has passed through each point of the incident plane at the target taken during a specified time increment.



Example of an Energy Pile.

5.1.3.3-15 <u>Spot Size</u> - This defines the effective size of an HEL beam upon a target. It is found by considering a plane intersecting the energy pile normal to the beam direction. The spot size is then the diameter of the circle formed by the intersection. (When the energy pile is not symmetrical about a point, an average diameter is used.) Note, any use of spot size is meaningless unless the total energy in the pile and the total energy contained in the spot size are also stated.

5.1.3.3-16 <u>Peak Intensity</u> - The highest intensity occurring within an HELWS beam, an instantaneous quantity.

5.1.3.3-17 <u>Average Peak Intensity</u> - This is the maximum intensity (joules/cm^2-sec) that develops in the energy pile of a HEL beam, divided by the accumulation time of the pile.

5.1.3.3-18 <u>Average Intensity</u> - This is the average intensity (joules/cm^2-sec) delivered by an HELWS upon a target during a given time increment. It is the total energy delivered within a spot size, divided by the product of the spot size area and the engagement time.

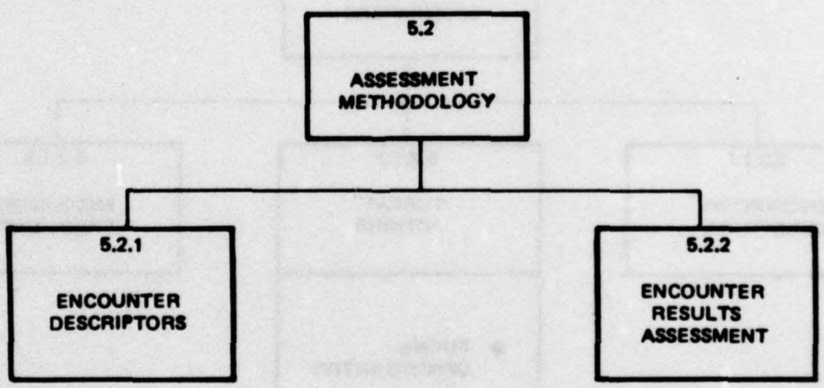
$$\text{AVERAGE INTENSITY} = \frac{\text{TOTAL ENERGY w/in SPOT}}{\text{(SPOT AREA) (ENGAGEMENT TIME)}}$$

It must be noted that the term average intensity is meaningless unless the spot size is completely defined (see 5.1.3.3-15).

5.2 Topical Field Term: Assessment Methodology

Definition: Those evaluation techniques and measures that are useful in the systematic quantification and evaluation of the vulnerability and survivability of an aircraft during operations in a man-made hostile environment.

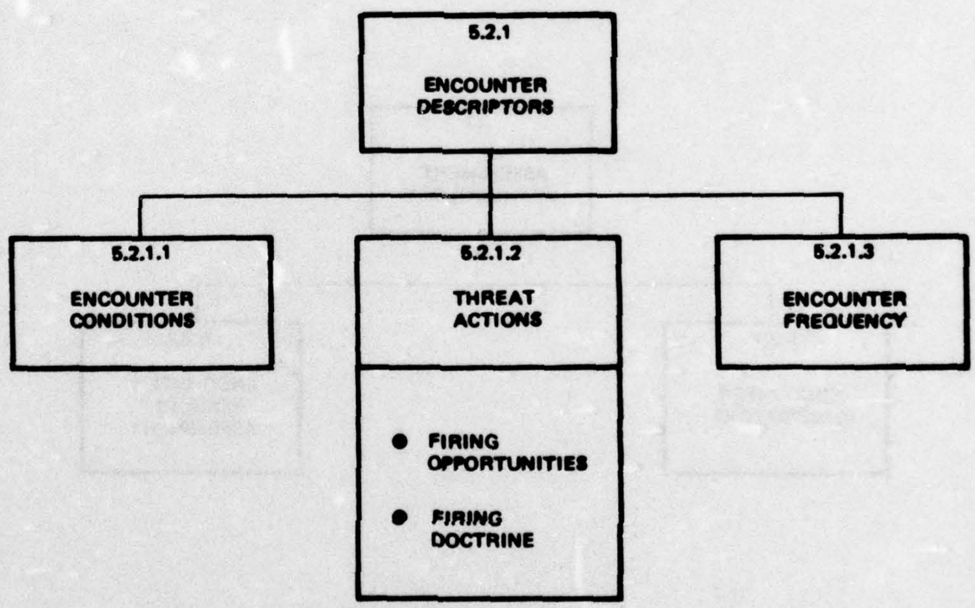
Explanatory Notes: The topical field "Assessment Methodology" contains terms which provide descriptive material on the threat/aircraft encounter situation and the resultant quantitative values for vulnerability and survivability of the aircraft. Accordingly, this topical field is subdivided into "Encounter Descriptors" and "Encounter Results Assessment". The "encounter descriptor" subfield contains terms which are used to describe the geometry of the encounter, weather conditions, and threat type and response. The "encounter results assessment" subfield contains terms which are used to describe aircraft survivability/vulnerability measures and techniques.



5.2.1 Subfield Term: Encounter Descriptors

Definition: Those mission parameters that characterize an engagement between aircraft and hostile defensive or offensive forces.

Explanatory Notes: The term "encounter descriptors" is used to represent that set of terms which best describes the prevailing conditions associated with an aircraft/threat encounter. These terms are used to describe environmental conditions, relative geometries between the aircraft and threat, time lines for the different encounter events, threat types, threat deployment/location, and threat responses to variations in environmental conditions and aircraft tactics. Accordingly, "encounter descriptors" has been subdivided as shown below.



5.2.1.1 Subfield Term: Encounter Conditions

Definition: Descriptors that characterize features of an encounter environment where these features are not necessarily inherent to either the aircraft or the hostile force, although they could derive from tactical considerations or from operational limitations.

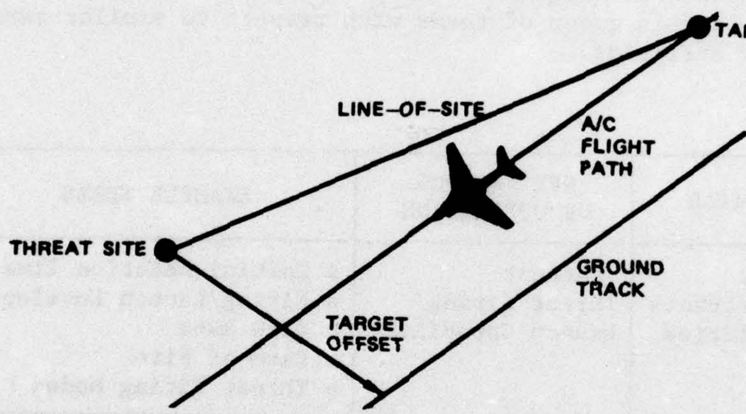
Explanatory Notes: The "encounter conditions" subfield represents those terms which are descriptors of the weather conditions, terrain, geometry, range, threat deployment, flight path, and similar factors. The table below clarifies the content of this group of terms with respect to similar terms in other subfields.

SUBFIELD	KEY FACTORS OF DEFINITION	EXAMPLE TERMS
5.1.2.2 Firing/Launch Capabilities	Inherent Threat Firing/ Launch Capability	o Initial Reaction Time o Firing/Launch Envelope o Slew Rate o Rate of Fire o Threat Firing Modes
5.2.1.1 Encounter Conditions	Encounter Characteristics	o Open-Fire Range o Target Offset o Target Angle Off
5.2.1.2.1 Firing Opportunities	Logical Use of Weapon in an Encounter	o Allowable Firing Sector o Unmask Range o Number of Rounds Fired
5.2.1.2.2 Firing Doctrine	Use of Firing Opportunities	o Barrage Fire o Fire-While-Track o Shoot-Look-Shoot

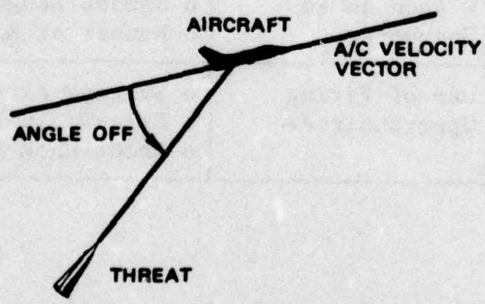
5.2.1.1-1 Threat Environment - Identification and specification of the types of enemy threats to be encountered, their number, their deployment enroute to and around target sites, and the type of warheads to be used.

5.2.1.1-2 Open-Fire Range - That aircraft/threat separation range at which the threat commences firing. The "open-fire range" is not necessarily the maximum effective range of the weapon. The open fire range is a function of threat tactics, aircraft flight conditions, terrain features, weather conditions, ECM environment, etc., as well as maximum effective range of the threat.

5.2.1.1-3 Target Offset - The minimum horizontal separation distance from the aircraft to a ground- or sea-based threat. "Target offset" is illustrated below.



5.2.1.1-4 Target Angle Off - An angle between the velocity vector of the aircraft and the line-of-sight between the target and threat. "Target angle off" is illustrated below. (See 5.2.2.1.2-5 for attack parameter definitions relative to the target.)

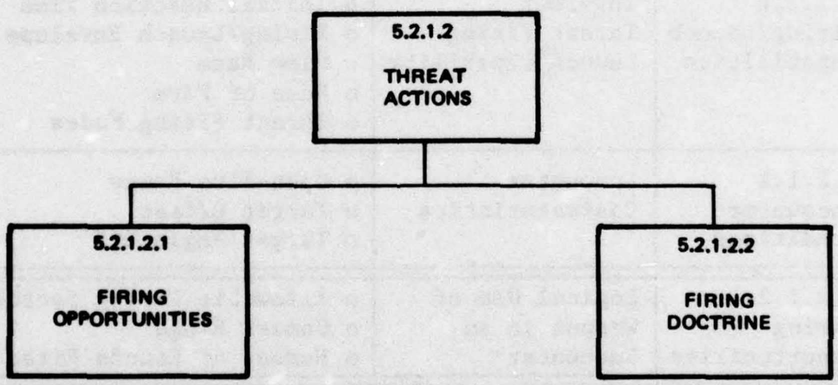


5.2.1.1-5 Distance to Cross-Over - If a perpendicular line is drawn from the ground gun or missile position to the closest point of approach of the target (in a fly-by), or to the closest point of approach projected (turn-away), the aircraft's distance from this point projected onto the ground plane is its distance from crossover.

5.2.1.2 Subfield Term: Threat Actions

Definition: Actions directly connected with the use of weapons by hostile forces under specified encounter conditions.

Explanatory Notes: The term "threat actions" represents those descriptors which define the capabilities and employment of threats in reaction to engagements with aircraft. The descriptive data associated with these threat reactions include the logical firing of weapons when the target can be impacted and the firing tactics employed during these potential impact periods. Accordingly, "threat actions" has been subdivided as shown below.



5.2.1.2.1 Subfield Term: Firing Opportunities

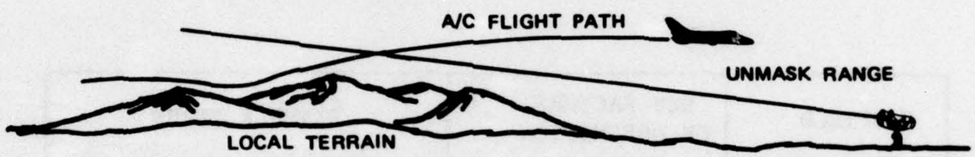
Definition: Those events in the sequence of an encounter during which hostile forces can logically use weapons against aircraft, defined in terms of number, nature, order, times, firing-mode feasibility, operational constraints, and similar descriptors.

Explanatory Notes: The "firing opportunities" subfield represents the firing/launch capabilities as constrained by the operational environment and the geometry associated with the threat/target encounter. The table clarifies the content of this group of terms with respect to similar terms in other subfields.

SUBFIELD	KEY FACTORS OF DEFINITION	EXAMPLE TERMS
5.1.2.2 Firing/Launch Capabilities	Inherent Threat Firing/ Launch Capability	o Initial Reaction Time o Firing/Launch Envelope o Slew Rate o Rate of Fire o Threat Firing Modes
5.2.1.1 Encounter Conditions	Encounter Characteristics	o Open-Fire Range o Target Offset o Target Angle Off
5.2.1.2.1 Firing Opportunities	Logical Use of Weapon in an Encounter	o Allowable Firing Sector o Unmask Range o Number of Rounds Fired
5.2.1.2.2 Firing Doctrine	Use of Firing Opportunities	o Barrage Fire o Fire-While-Track o Shoot-Look-Shoot

5.2.1.2.1-1 Allowable Firing Sector - A defined geographical or physical area into which a threat is permitted to fire. The "allowable firing sector" is that area in which a threat may take offensive action against an aircraft target. Limits on the threat's basic capability may be attributable to potential hazards to friendly troops, aircraft, etc.

5.2.1.2.1-2 Unmask Range - An aircraft/threat separation range at which the line-of-sight is unobstructed. The "unmask range" defines that separation range at which the threat-associated acquisition, detection, and tracking systems (visual, radar, IR, etc.) can freely view the aircraft. A sketch of this range is shown below.



5.2.1.2.1-3 Intervisibility - Intervisibility exists, between air and ground, when the aircraft reaches a point where there is no intervening terrain or vegetation. Essentially, this is the location where line-of-sight is unobstructed between aircraft and the ground observer, sighting device, or ground target in question.

5.2.1.2.1-4 Number of Rounds Fired - The number of rounds each threat type fires at each aircraft target. The number of rounds depends upon firing doctrine, terrain features, ECM, tactics, etc.

5.2.1.2.2 Subfield Term: Firing Doctrine

Definition: The manner in which forces use (plan to use) their firing opportunities; also, the set of criteria employed by the force in structuring its plan.

Explanatory Notes: The "firing doctrine" subfield represents the usage of the weapon-firing opportunities dictated by tactics. The table below clarifies the content of this group of terms with respect to similar terms in other subfields.

SUBFIELD	KEY FACTORS OF DEFINITION	EXAMPLE TERMS
5.1.2.2 Firing/Launch Capabilities	Inherent Threat Firing/ Launch Capability	o Initial Reaction Time o Firing/Launch Envelope o Slew Rate o Rate of Fire o Threat Firing Modes
5.2.1.1 Encounter Conditions	Encounter Characteristics	o Open-Fire Range o Target Offset o Target Angle Off
5.2.1.2.1 Firing Opportunities	Logical Use of Weapon in an Encounter	o Allowable Firing Sector o Unmask Range o Number of Rounds Fired
5.2.1.2.2 Firing Doctrine	Use of Firing Opportunities	o Barrage Fire o Fire-While-Track o Shoot-Look-Shoot

5.2.1.2.2-1 <u>Barrage Fire</u> - A firing doctrine or mode, typically associated with small arms, antiaircraft artillery, and HELWS, in which the threat continuously fires into a localized sector; no target tracking or round-to-round lead angle estimation is utilized. "Barrage fire" has been used by defenses when (1) insufficient time is available to establish a tracking solution, (2) aircraft penetration tactics or ECM environment prohibits use of a fire-while-track-mode, or (3) the penetrating aircraft flight path or penetration corridor is known such that the defense can optimize its effectiveness by massing threats in a localized area.

5.2.1.2.2-2 <u>Fire-While-Track</u> - A firing doctrine, or mode, typically associated with antiaircraft artillery, in which the threat continuously tracks and fires at an aircraft within its allowable firing sector. The "fire-while-track" firing mode is normally utilized by weapons systems that have an integrated capability to continuously predict lead angles, position (aim), and fire at aircraft. The effectiveness of this firing doctrine depends upon such factors as the threat slew rate, rate-of-fire, range effectiveness, lead angle prediction capability, etc.

5.2.1.2.2-3 <u>Shoot-Look-Shoot</u> - A firing doctrine normally used by surface-to-air gun and missile sites in which miss distance or damage assessment is made between successive bursts of fire or launchings. The "shoot-look-shoot" doctrine is normally used by long range systems with guided weapons (i.e., SAMs) that have a relatively high single-shot kill probability as a means of optimizing total system effectiveness.

5.2.1.3 Subfield Term: Encounter Frequency

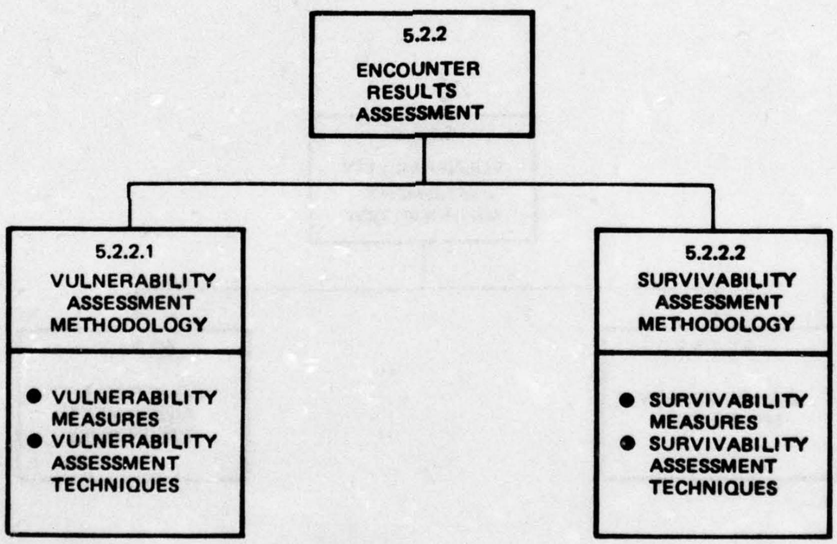
Definition: A measure giving the repetition factor expected to apply to specific encounter conditions.

Explanatory Notes: This measure is normally expressed in terms of expected encounters per sortie (per unit distance, per unit time, per target, or other similar unit), thus providing quantification of the significance of the specific encounter condition in the total mission environment. Weighting or scaling factors may also be used to determine expected sorties per unit in relative terms.

5.2.2 Subfield Term: Encounter Results Assessment

Definition: Systematic description, delineation, and quantification of the expected results of an engagement between aircraft and hostile forces.

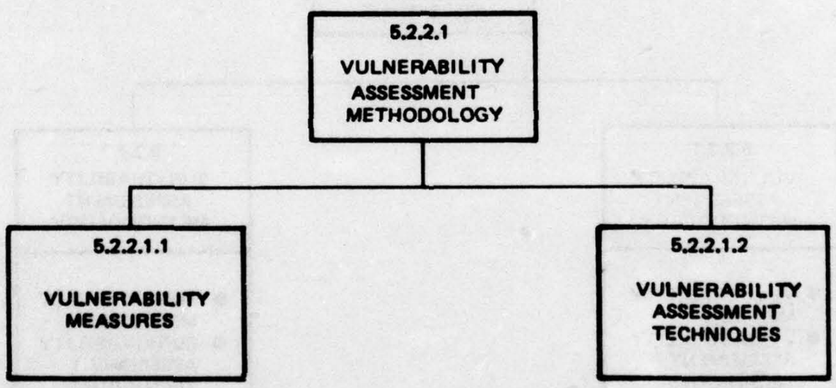
Explanatory Notes: The assessment of an encounter between an aircraft and hostile forces requires knowledge of both aircraft vulnerability and those factors that influence the probability of receiving a hit. Accordingly, "encounter results assessment" is subdivided into the following subfields:



5.2.2.1 Subfield Term: Vulnerability Assessment Methodology

Definition: Those measures and techniques employed in the systematic description, delineation, and quantification of the vulnerability of an aircraft when subjected to threat mechanisms.

Explanatory Notes: The "vulnerability assessment methodology" subfield contains those terms which are used to identify both the vulnerability measures and the assessment techniques employed in quantitatively measuring and analyzing the response of an aircraft when subjected to threat mechanisms. Accordingly, "vulnerability assessment methodology" has been subdivided as shown below.



5.2.2.1.1 Subfield Term: Vulnerability Measures

Definition: Terms used to define, describe, delineate, distinguish, and quantify the vulnerability of an aircraft in encounters with hostile forces.

Explanatory Notes: Numerous descriptors and summary "vulnerability measures" have been used to describe the response of components, subsystems, and systems when subjected to threat mechanisms. In general, these summary measures can be categorized into one of the following classes: (1) time-to-failure, (2) probability of occurrence (of a particular damage and failure mode), (3) vulnerable area, and (4) composite loss factor that is normally the vulnerable area or probability of occurrence weighted by threat encounter frequency. These measures are not independent, and the choice of which measure to use depends on the particular application - aircraft type, aircraft design status (predesign, detailed design, or design retrofit), threat type, associated threat mechanisms, and so forth.

5.2.2.1.1-1 Ballistic Vulnerability - measure of the vulnerability of an aircraft to threat mechanisms associated with ballistic impacts. Typical measures of "ballistic vulnerability" include vulnerable area, probabilities of occurrence of various damage and failure modes, times-to-failure, etc. Each of these measures must be referenced to a specific kill level.

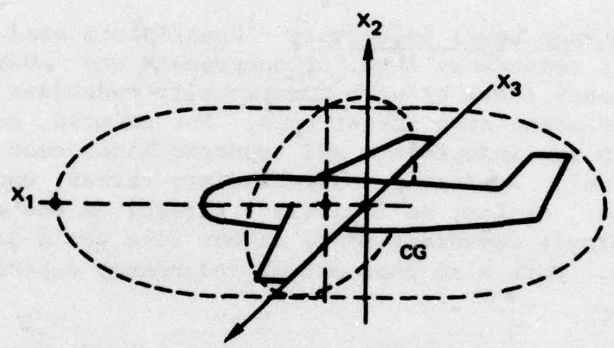
5.2.2.1.1-2 Vulnerable Area (Av) - A quantitative measure of the ballistic vulnerability of a target or target element expressed in areal dimensions (square feet, square meters, etc.). Typically, the "vulnerable area" of a target is computed as the product of the presented area of that target in a plane normal to the trajectory of the ballistic threat mechanism, and the probability of kill of that component given a hit on the target by the ballistic threat mechanism.

5.2.2.1.1-3 Component Vulnerable Area - A vulnerable area calculated for each component that is independent of any interfacing effects with other critical components other than shielding. "Component vulnerable area" is a measure of each component's inherent vulnerability without considering any mitigating or interfacing effects, other than shielding, with other critical components that may comprise the total target. Hence, component vulnerable area is computed as though that component were the only critical component in the target.

5.2.2.1.1-4 Component Incremental Vulnerable Area - A vulnerable area calculated in such a way that the vulnerability interface with other critical components in the target is maintained. "Component incremental vulnerable area" is a measure of each component's inherent vulnerability including any mitigating or interfacing effects with other critical components that may comprise the total target.

5.2.2.1.1-5 Total Target Vulnerable Area - The sum of component incremental vulnerable areas. The "total target vulnerable area" is a summary vulnerability measure, usually expressed in square feet, that appropriately synthesizes individual component vulnerable areas. Typically, these values are stated per threat type (e.g., 23mm HE-I), impact velocity, kill level, attack aspect (or view), etc.

5.2.2.1.1-6 External Blast Vulnerability - A measure of the vulnerability of an aircraft to externally-detonated-blast threat mechanisms. In general, lethal blast envelopes, as shown below, are used to describe the vulnerability of aircraft to externally-detonated-blast threat mechanisms. These envelopes represent a synthesis of the damaging effects attributable to external blast waves (i.e., catastrophic structural failure, stability/control loss, and critical subsystem failure) and present the critical ranges from the aircraft within which a detonation of a particular explosive weight could yield damaging effects. Normally, these envelopes are prepared as functions of altitude and standardized charge weight.



5.2.2.1.1-7 Interdependent Component - A component whose vulnerability contribution to its subsystem and the total weapon system, exclusive of shielding, is influenced by its locational interface with other components and subsystems. The term "interdependent" is used to describe components whose locational interface with other components can significantly influence total aircraft vulnerability. For example, consider a fuel line located (1) in a compartment containing an ignition source (e.g., hot surface) and (2) in a compartment isolated from ignition sources. In the first case, a fuel leak will result in a fire whereas in the second case no immediate fire would result. Hence, the fuel line would be classified as interdependent. This can be contrasted to non-interdependent components such as a computer or sensor whose inherent damage susceptibility does not depend on the locational interface with other components.

5.2.2.1.1-8 Total System Level Redundancy - Descriptors used to identify the functional or inherent redundancy level of a subsystem as measured at the total system level. These descriptors (dual redundant, quad redundant, etc.) are used to define the inherent, functional, or design redundancy level of each subsystem. This classification is made independent of threat type and is chosen to identify the maximum redundancy level of each of the included components. For example, a hydraulic system with two separated power supplies would be termed dual even though both systems interfaced at a single actuator.

5.2.2.1.1-9 Component Redundancy Level - A number of similar components, devices, structural elements, parts, or mechanisms used to support the functional redundancy of a system or subsystem. The level of redundancy refers to the number of similar elements (components, etc.) used to create redundant subsystems. This term is used as a descriptor for each component and is not a descriptor of the total subsystem. For example, a system may include four independent, identical elements (accelerometers) to measure acceleration and only one element (computer) to accept or use the acceleration value. In this case, the accelerometers are quad redundant and the computer is singly redundant (i.e., the level of redundancy equals one).

5.2.2.1.1-10 Branch Level Redundancy - Descriptors used to identify the threat-dependent redundancy level of components and subsystems. The "actual" redundancy level of each functionally redundant component and subsystem is dependent upon threat type. For example, consider a fuel feed system with two independent and separate lines each capable of supplying engine fuel. Against a non-incendiary threat, each line would be doubly redundant. Against an incendiary threat, on the other hand, each line would be singly redundant since either line could provide the source for a fuel fire. Note also that actual redundancy depends upon kill level.

5.2.2.1.1-11 Probability of Kill Given a Hit ($P_{K/H}$) - The probability of obtaining a level of damage on a target which causes sufficient performance degradation to classify the target as killed given a hit on the target by a threat mechanism. (See Subfield 5.3.3 for discussion of the term "kill".) The probability of kill given a hit can be expressed as

$$P_{K/H} = P_{D/H} \cdot P_{K/D}$$

where

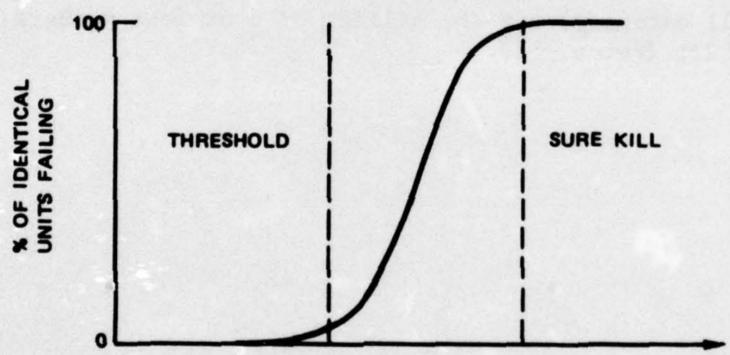
$P_{D/H}$ = probability of obtaining a specified level of damage on a target given a hit on the target and

$P_{K/D}$ = probability of sufficient performance degradation to classify the target as killed given the specified level of damage.

5.2.2.1.1-12 Component Probability of Kill Given a Hit - The probability of obtaining a level of damage on a component which causes sufficient performance degradation to classify the component as killed given a hit on the component by a threat mechanism. This probability term is also used to quantitatively describe the response of a component when subjected to a threat mechanism, such as "the probability of obtaining a fuel cell fire given fuel cell penetration and incendiary function".

5.2.2.1.1-13 Probability of Kill Given Lock On ($P_{K/LO}$) - The probability of obtaining a desired level of damage on a target given lock on (as defined in 5.1.3.1-6). In contrast to $P_{K/H}$, the probability of hit at each point on the target is incorporated with the probability of target kill given a hit at that point and integrated over the target to give an overall kill probability. $P_{K/LO}$ is the appropriate kill probability for aimpoint designated weapons (i.e., for those whose hit probability is not uniform over the entire target surface), for which $P_{K/H}$ can not be factored out of the overall kill probability. For a HELWS, $P_{K/LO}$ should also include probability of component failure as a function of delivered energy density, spot size, etc. The probability of a kill at each point on the target can be subdivided into the product of the probability of damaging the critical component and one minus the component non-criticality probability given that damage to the component has been achieved.

5.2.2.1.1-14 Component Conditional Kill Probability ($P_{CC/K}$) - The probability of obtaining a desired level of damage on a critical component. This probability arises from the fact that identical components do not always fail at the same absorbed energy density, but over a range of energy densities, as shown below



Accumulated Energy Density

5.2.2.1.1-15 Component Non-Criticality Probability (P_{NC}) - The probability that, given enough damage to have killed a supposedly critical component, the target will not sustain the desired level of kill. An example would be the interaction of a HEL beam and an externally attached bomb. Assume that, for a given irradiation, there is a 20% probability that the bomb will undergo a high order detonation; the other 80% of the time the bomb will undergo non-critical low order detonation, burn, be released, etc. Further, assume that the target will sustain killing damage in only 70% of the high order detonations. Then,

$$P_{NC} = 1 - (0.2)(0.7) = 0.86$$

or, the component will not be critical to the target 86% of the time.

5.2.2.1.1-16 Singly Vulnerable - The property attributed to a component if the killing of that component is sufficient to result in an aircraft kill in a specified kill category.

5.2.2.1.1-17 Non-Singly Vulnerable (also called Multiply Vulnerable) - The property attributed to components of a set when the killing of less than n members of the set does not result in an aircraft kill (in a specified kill category) but the killing of n or more members does result in a kill (for n > 1).

5.2.2.1.2 Subfield Term: Vulnerability Assessment Techniques

Definition: Methods and procedures useful in the systematic delineation and quantification of the vulnerability of an aircraft in encounters with hostile forces.

Explanatory Notes: This subfield represents the data and methodologies required to determine the vulnerability of an aircraft, or parts thereof, assuming an impact (i.e., no threat error sources are present) in the encounter. The delineation and quantification of vulnerability may be in terms of degrees of severity, probabilities, or other descriptors that provide statistical or categorical content. The table below clarifies the content of this group of terms with respect to similar terms in other subfields.

SUBFIELD	KEY FACTORS OF DEFINITION	EXAMPLE TERMS
5.1.3.1 Fire Control Factors	Initial Error and Other Factors	o Tracking Error o Aiming Error o Lead Angle Prediction
5.1.3.2 Trajectory Factors	Transit Error and Other Factors	o Gravity Drop o Ballistic Dispersion o Thermal Blooming
5.2.2.1.2 Vulnerability Assessment Techniques	Exclusive of Error; Impact Is Assumed	o Penetration Impact Conditions o Grid Size o Attack Aspect o Equivalent Density
5.2.2.2.2 Survivability Assessment Techniques	Final Errors and Other Factors	o Hit Distribution o Total Weapons System Dispersion o Dynamic Fragment Spray Angles

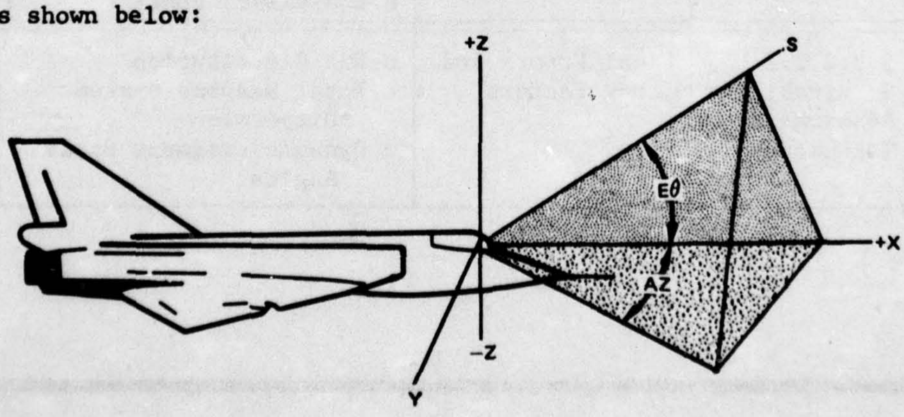
5.2.2.1.2-1 Striking Velocity (V_S) - The relative velocity between the target and the impacting fragment, projectile, or other damage mechanism at the instant of impact.

5.2.2.1.2-2 Penetration Impact Conditions - The characteristics of a fragment, projectile, or similar threat mechanism at the moment of impact with a target. The impact conditions are normally expressed in terms of the striking velocity, mass, obliquity angle, etc. for penetrators or fragments. This data is then used to determine penetration capability, residual mass/velocity, etc., for use in the assessment of target vulnerability.

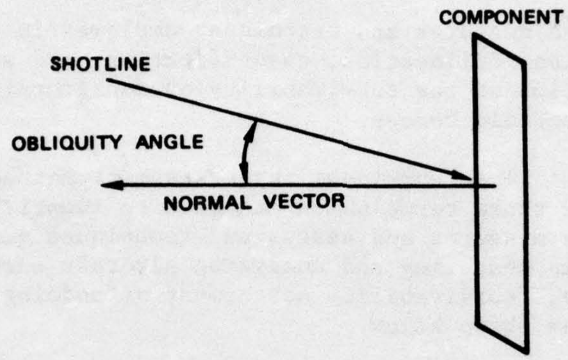
5.2.2.1.2-3 Shotline - A mathematical line originating at some point on a grid plane and extending algebraically through a mathematically described target. The shotline is normally designed to predict the possible trajectory of some threat through a target. Each shotline is typically used to predict thickness and angle of every intersection made with elements of the target being described. Since each shotline originates in a small grid cell on a plane, it is intended to be a typical representation of all other possible shotlines that could be drawn through that grid cell. The shotline intersection information is normally computer-generated by programs such as SHOTGEN or MAGIC.

5.2.2.1.2-4 Grid Size - The fineness of the mesh used to define the shotline locations in a ray-tracking program. The area of one grid cell is normally represented by one shotline in a ray-tracing routine. The typical assumption made is that all rays originating in one grid cell would pass through roughly the same elements of the target. The best accuracy but longest computational time are obtained with the smallest possible grid size.

5.2.2.1.2-5 Attack Aspect - Azimuth and elevation angles, measured with respect to a target-located coordinate system, of the shotlines generated by a target-description program such as MAGIC or SHOTGEN. The specific target-located coordinate system used depends upon the particular procedure employed. An example of one such coordinate system is shown below:



5.2.2.1.2-6 Obliquity Angle - The angle between a shotline through a component and the normal vector to the component at the point of shotline intersection. The obliquity angle is shown below.



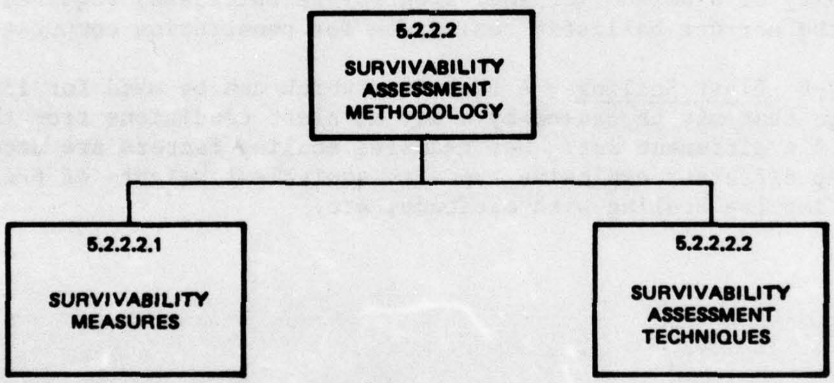
5.2.2.1.2-7 Equivalent Density - The value of density resulting when the actual measured density of a component is reduced analytically to that density of aluminum (or equivalent plate thickness) required to produce the correct ballistic resistance for penetration computations.

5.2.2.1.2-8 Blast Scaling - A technique which can be used for inferring the damage that may be caused by a set of blast conditions from the results of a different set. For example, *scaling factors are used for* converting different explosive types to equivalent weights of pentolite, pressure/impulse scaling with altitude, etc.

5.2.2.2 Subfield Term: Survivability Assessment Methodology

Definition: Those measures and techniques employed in the systematic description, delineation, quantification, and statistical characterization of the survivability of an aircraft in encounters with hostile forces.

Explanatory Notes: The "survivability assessment methodology" subfield contains those terms which are used to identify both the survivability measures and assessment techniques quantitatively employed in measuring and analyzing aircraft survivability. Accordingly, "survivability assessment methodology" has been subdivided as shown below.



5.2.2.2.1 Subfield Term: Survivability Measures

Definition: Terms used to define, describe, delineate, distinguish, and quantify the survivability of an aircraft in encounters with hostile forces.

Explanatory Notes: Numerous descriptors and summary measures have been used to define the result of engagements between aircraft and hostile forces. In general, these measures address the probability of survival per shot, or shots, site, sortie or other unit measure. Once the probability of survival has been determined, other summary and comparative measures are used. Some of these are: losses per 1000 sorties, expected combat lifetime (in sorties), and so forth. It is important to note that all of these survivability measures are referenced to specific kill levels. For example, probability of surviving for 5 minutes following threat impact, etc.

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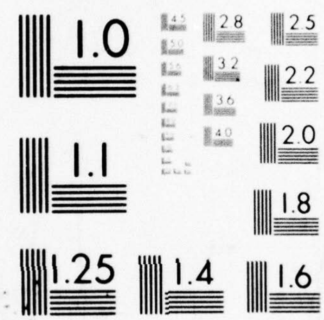

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5.2.2.2.1-1 Aircraft Probability of Survival (P_S) - The probability that an aircraft will survive a defined damage level in specified threat engagements. "Aircraft probability of survival" is a summary measure that combines total threat system effectiveness (from initial detection and acquisition through weapons launch to weapon impact) and target (aircraft) vulnerability. In general, probability of survival is computed from an in-depth assessment of all factors that influence threat effectiveness and target vulnerability. However, depending on the particular application, aircraft probability of survival measures may be computed for various aspects of a complete mission such as probability of survival per encounter, probability of survival per sortie, etc.

5.2.2.2.1-2 Probability of Survival per Encounter - The probability that an aircraft will survive a defined damage level in a single encounter with a specified threat. An example of those factors that are normally considered in determining the "probability of survival per encounter", $P_{S/E}$, is shown below.

$$P_{S/E} = (P_{LOS})(P_D)(P_L)(P_G)(P_{DET}) \left[\prod^{n} (1 - P_{SSK}) \right]$$

where:

P_{LOS} = Probability of line-of-sight to the target

P_D = Probability of detection, given line-of-sight

P_L = Probability of launch or firing, given detection

P_G = Probability of successful guidance, given launch or firing

P_{DET} = Probability of warhead detonation (fuzed warheads), given successful guidance

n = Number of shots fired during a pass

P_{SSK} = Single-shot kill probability

5.2.2.2.1-3 Probability of Survival per Sortie (P_{SM}) - The probability that an aircraft will survive a defined damage level in a single operational flight during which it may have multiple engagements with the various weapons of a zone defense. P_{SM} is calculated by the following expression.

$$P_{SM} = \sum_i P_{S_i} = \sum_i \exp\left[-\frac{N_i\, D\, 2R_{eff_i}\, (1 - P_S/E_i)}{A_i}\right]$$

where:

P_{SM} = Probability of mission survival over i^{th} engagements with the zone defense weapons mixture

A_i = The area in which the weapon systems or firing units are expected to be randomly distributed

N_i = The number of i^{th} type weapon systems in area A

R_{eff_i} = The effective range of the i^{th} type weapon system

D = The distance the aircraft flies through area A without significantly changing altitude or airspeed

P_S/E_i = The probability of the aircraft surviving a single encounter with the i^{th} type weapon system at a given airspeed and altitude

P_{S_i} = Probability of surviving multiple engagements with the i^{th} type weapon system.

5.2.2.1-4 Single-Shot Probability of Hit (P_{SSH}) - The probability of hitting an aircraft given a single firing from a threat. The single-shot probability of hit can be computed in many ways. An example of one procedure applicable to AAA is shown below. (This example assumes that the distribution of hits is circular normal.)

$$P_{SSH} = \frac{A_p \exp(-b^2/2\sigma^2)}{2\pi\sigma^2}$$

5.2.2.2.1-5 Single-Shot Kill Probability (P_{SSK}) - The probability that an aircraft will be killed to a defined kill level by a single firing from a threat. The "single-shot kill probability," P_{SSK}, is a summary measure that combines weapon system accuracy (i.e., single-shot probability of hit, P_{SSH}) and target vulnerability (i.e., probability of kill, given a hit, $P_{K/H}$) for individual shots. In general, P_{SSK} is computed as shown below.

$$P_{SSK} = P_{SSH} P_{K/H}$$

5.2.2.2.1-6 Single Burst Kill Probability (P_{KE}) - The probability that an aircraft will be killed by a single exposure to the burst of a specific internally-detonated round given a particular set of encounter conditions. For a specific warhead and set of encounter conditions, P_{KE} can be obtained by means of the expression shown below.

$$P_{KE} = 1 - \exp(-E_K) = 1 - \exp(-\rho A_V)$$

where:

E_K = the expected number of lethal hits,

A_V = the aircraft vulnerable area at the aspect under consideration, and

ρ = the average number of fragments per unit area incident on A_V.

5.2.2.2.1-7 Expected Combat Lifetime - Expected number of combat sorties an aircraft can perform before suffering an attrition kill. Normally, this lifetime is computed as the probability of survival divided by the probability of kill, where these probabilities are referenced to the same kill level.

5.2.2.2.1-8 Loss Rate - A predicted measure of the sortie survivability of aircraft. This rate is normally measured in terms of expected losses per designated number of sorties; i.e., an aircraft with a probability of survival of 0.99 per sortie has a loss rate per 1000 sorties of 10.

5.2.2.2.2 Subfield Term: Survivability Assessment Techniques

Definition: Methods and procedures useful in the systematic delineation and quantification - in terms of degree of severity, probabilities, and other descriptors which provide statistical or categorical content - of the survivability of an aircraft in encounters with hostile forces.

Explanatory Notes: The "survivability assessment techniques" subfield represents the data and methodologies required to combine the final errors of the weapon firing and the aircraft vulnerability so as to determine the aircraft survivability in a threat encounter. The table below clarifies the content of this group of terms with respect to similar terms in other subfields.

SUBFIELD	KEY FACTORS OF DEFINITION	EXAMPLE TERMS
5.1.3.1 Fire Control Factors	Initial Error and Other Factors	o Tracking Error o Aiming Error o Lead Angle Prediction
5.1.3.2 Trajectory Factors	Transit Error and Other Factors	o Gravity Drop o Ballistic Dispersion o Thermal Blooming
5.2.2.1.2 Vulnerability Assessment Techniques	Exclusive of Error; Impact Is Assumed	o Penetration Impact Conditions o Grid Size o Attack Aspect o Equivalent Density
5.2.2.2.2 Survivability Assessment Techniques	Final Errors and Other Factors	o Hit Distribution o Total Weapons System Dispersion o Dynamic Fragment Spray Angles

5.2.2.2.2-1 Diffuse Target - A mathematical representation of a target which assumes that the kill probability is unity for a burst occurring at the target center and is zero at burst points infinitely remote from the target center. The kill probability, as a function of burst point location, has the general form of a Gaussian probability curve symmetrical about the target center. This "diffuse target" representation is frequently used in the development of single-shot probability of kill representations. The general form of the kill probability, $P_K(r)$, is shown below.

$$P_K(r) = \exp\left(-r^2/2\sigma^2\right)$$

where r is the distance from the target center to the burst point and σ is defined as the vulnerable radius or lethal radius of the target for the particular threat type.

5.2.2.2.2-2 Hit Distribution - A mathematical representation that defines the results of a firing pass on an aircraft in terms of the probability of n hits. An assumption is that the hit distribution follows the Poisson distribution, i.e.,

$$P(n) = \frac{E^n e^{-E}}{n!}$$

where P(n) is the probability of exactly n hits and E is the expected number of hits (per firing pass). The value of E is normally computed from an assessment of the total errors involved in the firing pass.

5.2.2.2.2-3 Total Weapon System Dispersion - A summary measure of the inherent accuracy of a weapon system, exclusive of bias errors, described in terms of the standard deviation of the burst pattern. The total system dispersion is a composite measure of the error contributions of all sources - tracking error, aiming error, ballistic dispersion, etc. For independent error sources, the total weapon system dispersion, σ, is computed below.

$$\sigma = \left\{\Sigma\, \sigma_i^2\right\}^{1/2}$$

where σ_i are the individual contributors.

5.2.2.2.2-4 Round-to-Round Correlation - Error analysis procedures that take into account the serial correlation between successive rounds. Subsequent events (e.g., component errors) are made to be appropriately dependent on preceding ones. For example, the error in parameter y at time $(t + \Delta t)$ is related to the error at time t by

$$Ey\ (t + \Delta t) = Ey(t) \cdot C\ (\Delta t) + Ey'(t + \Delta t)$$

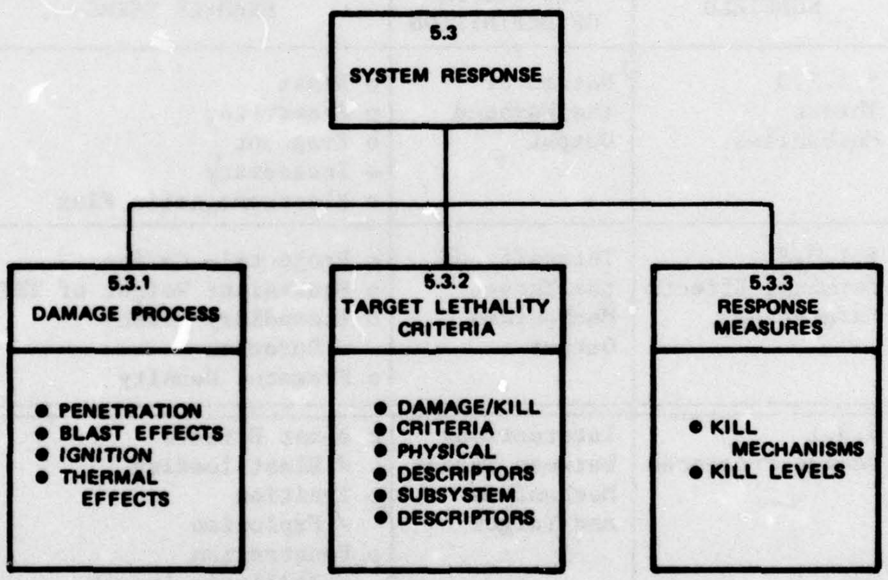
where $Ey(t)$ is the error at time t, $Ey'\ (t + \Delta t)$ is the raw error in y at time $(t + \Delta t)$, and $C\ (\Delta t)$ is the serial correlation coefficient which relates the significance of the previous error to the present error. As $C(\Delta t)$ tends toward one, the raw error is added to more and more of the previous error. Likewise as $C(\Delta t)$ tends toward zero, there is less dependency between subsequent errors.

5.2.2.2.2-5 Dynamic Fragment Spray Angles - A skewing of the static fragment spray angles by the velocity of the warhead at detonation.

5.3 Topical Field Term: System Response

Definition: The reactions of a system, including crew station, structure, and subsystems, when a threat is detected or the system is subjected to a threat mechanism.

Explanatory Notes: The "system response" topical field contains those elements which are used to describe (1) the interactions of threat mechanisms and a target (e.g., blast/blast effects), (2) the inherent damage susceptibility of a target, and (3) response measures. These major subfields are depicted below.



5.3.1 Subfield Term: Damage Processes

Definition: Descriptors of the nature, type, form, or state of the interaction between the threat mechanism and the target or target element.

Explanatory Notes: The "damage processes" subfield consists of descriptors of the interactions between threat mechanisms and the target. Accordingly, this subfield is divided into four lower-order subfields: penetration, blast effects, ignition, and thermal effects. The table below clarifies the content of this term as distinguished from terms and meanings with which it might be confused.

SUBFIELD	KEY FACTORS OF DEFINITION	EXAMPLE TERMS
5.1.1.3 Threat Mechanisms	Nature of the Warhead Output	o Blast o Penetrator o Fragment o Incendiary o Electromagnetic Flux
5.1.3.3 Terminal Effects Parameters	Intensity of the Threat Mechanisms Output	o Projectile Caliber o Equivalent Weight of TNT o Incendiary Flash Duration o Fragment Density
5.3.1 Damage Processes	Interactions between Threat Mechanisms and Target	o Blast Effects ✓ Blast loading o Ignition ✓ Explosion o Penetration ✓ Ballistic impact o Thermal Effects ✓ Impulse loading

5.3.1.1 Subfield Term: Penetration

Definition: A damage process relating to the ability of a threat mechanism to force a way into or through a target or target element.

Explanatory Notes: Penetration is a damage process typically associated with a penetrator or fragment. The net effect of a penetration may be a fluid leak, a fluid pressure pulse, control linkage severance, impact damage, or the like.

5.3.1.1-1 <u>Ballistic Impact</u> - Those impacts due to hits on the target by projectiles, fragments or other aerodynamically-effected threat mechanisms.

5.3.1.1-2 <u>Ballistic Load</u> - The transient load on a target structure which is a result of a ballistic impact.

5.3.1.1.3 <u>Hydraulic-Ram Effect</u> - The development, in a fluid, of shock waves of potentially destructive intensity to tank walls and fuel lines caused by a ballistic penetrator passing through the fluid. The kinetic energy of the penetrator is converted to hydraulic pressure energy in the fluid as the penetrator is slowed by viscous drag. This hydraulic pressure energy can occur in the form of fluid-pressure surges or pulses.

5.3.1.1-4 <u>Burn Through</u> - The penetration of a surface by burning or melting through the surface material, as by a HEL beam.

5.3.1.2 Subfield Term: Blast Effects

Definition: A damage process relating to the ability of a threat mechanism to produce sufficient pressure forces to impose structural degradation, geometrical deformation, or other types of damage on a target or target element.

Explanatory Notes: "Blast effects" are damage processes typically associated with high-explosive warheads such as contained in large AAA projectiles or surface-to-air and air-to-air missiles. Depending on the threat and fuze type, the blast pressures may be external or internal to the aircraft.

5.3.1.2-1 Blast Loading - The force on an object caused by an air blast from an explosion striking and following around the object. It is a combination of overpressure (or diffraction) and dynamic pressure (or drag) loading.

5.3.1.2-2 Face-on Impulse - The impulse experienced by a target surface as the shock wave from an explosion is reflected from it.

5.3.1.2-3 Face-on Pressure - The pressure experienced by a target surface as the shock wave from an explosion is reflected from it.

5.3.1.2-4 Side-on Impulse - The impulse which a target surface would experience as the shock wave from an explosion moves parallel to it.

5.3.1.2-5 Side-on Pressure - The pressure which a target surface would experience as the shock wave from an explosion moves parallel to it.

5.3.1.3 Subfield Term: Ignition

Definition: A damage process relating to the ability of a threat-mechanism to create a condition suitable for the combustion of flammable materials.

Explanatory Notes: "Ignition" is a damage process generally associated with incendiary-type threats such as armor-piercing incendiaries (AP-I), high-explosive incendiaries (HE-I), and so forth. However, additional threat mechanisms, such as thermal energy, can create conditions (e.g., a fuel leak in a voided area) to initiate combustion.

5.3.1.3-1 Explosion - A specific form of a fire where rapid burning of flammable vapors causes high gas pressures to be generated within a confined space. The conditions governing the occurrence of a fuel-tank explosion are of particular interest in assessing target response and measuring target vulnerability. Some conditions to be considered are temperature, pressure, fuel-air mixture, ullage mixture, path of ignition source, etc.

5.3.1.3-2 Ignition Source - A mechanism that increases the temperature of combustible material to the temperature at which ignition occurs. "Ignition sources" may be directly related to or contained within the impacting threat mechanism, or may be the result of weapon effects on the target. An example of the former type is burning incendiary and flash effects due to penetration of metallic materials by high velocity projectiles or fragments. Examples of the latter type are spontaneous combustion due to oxygen, liberated by weapon effects, combining with suitable material to allow ignition, and flammable material ignition from shorted electrical equipment or cabling.

5.3.1.3-3 Vaporific Flash - Incandescent metal particles or vapor generated by impact of nonincendiary projectiles or fragments upon a target or target element.

5.3.1.3-4 Hot-Surface Ignition - A fire ignited from a hot or heated surface. "Hot surface ignition" sources are usually categorized as hot wires, friction or impact sparks, and extended surfaces such as hot engine bleed air and exhaust ducts.

5.3.1.3-5 Hot-Gas Ignition - A fire ignited from a hot gas. Pilot flames, hot gas jets, adiabatic composition and shock wave compression are the categories of mechanism for ignition independent of surfaces.

5.3.1.3-6 Quenching Distance - The smallest gap between two parallel plates that will just allow a flame to pass.

5.3.1.3-7 Flame Velocity - The velocity with which a flame front advances into a mass of quiescent unburned reactants, or conversely, the velocity with which a moving mass of unburned reactants approaches a stationary flame front.

5.3.1.4 Subfield Term: Thermal Effects

Definition: A damage process, exclusive of ignition, relating to the ability of a threat mechanism to deposit sufficient quantities of heat to impose structural degradation, geometrical deformation, or other types of damage on the target or target element.

Explanatory Notes: Thermal effects are damage processes related to nonnuclear radiation-type threats, typically HELWS, that are capable of delivering a critical energy density on targets.

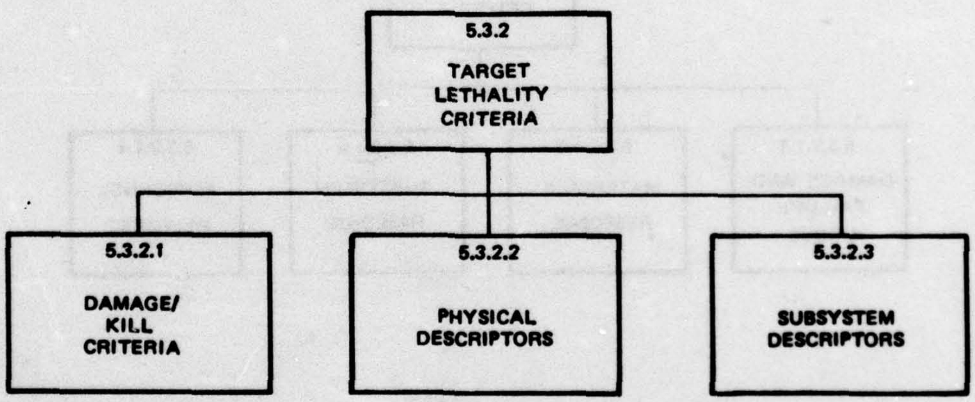
5.3.1.4-1 <u>Impulse Loading</u> - The ejection of a high-velocity vapor from an irradiated surface resulting in an intense wave propagating through the material with spallation on the back surface.

5.3.1.4-2 <u>Thermal Shock</u> - Thermally-induced stresses resulting from a rapid local heating or cooling of a metal. Rupture may occur if the induced stresses exceed the material's ultimate strength.

5.3.2 Subfield Term: Target Lethality Criteria

Definition: Quantitative and qualitative data that collectively define (1) the susceptibility of the target to damage processes and (2) the resultant responses of the target, given that threat-induced damage occurs.

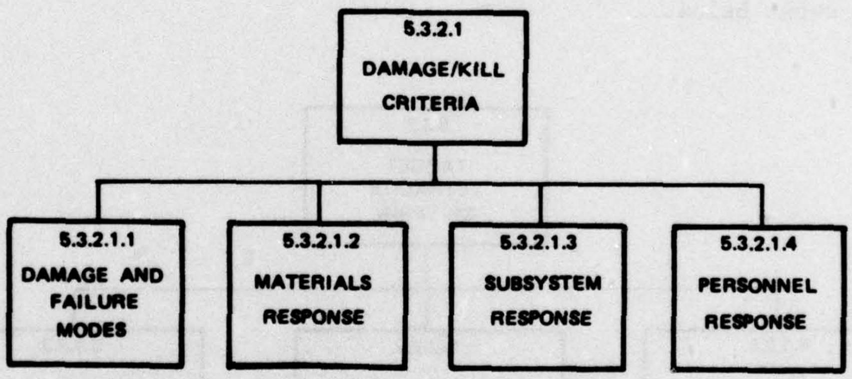
Explanatory Notes: The term "target lethality criteria" is used to represent that collection of data which taken together describe the target in sufficient detail such that a vulnerability assessment to any type of threat can be made. In general, target lethality criteria data are independent of specific threat types but relate to the nature of damage processes. Accordingly, terms are included which are used to identify (1) the response of the target (i.e., aircraft) to assumed levels of damage, and the response of materials, subsystem, and personnel to damage processes, (2) physical descriptors of the target, and (3) other useful terms (subsystem descriptors) which imply the vulnerability nature of the target. The subdivision of "target lethality criteria" is shown below.



5.3.2.1 Subfield Term: Damage/Kill Criteria

Definition: Quantitative and qualitative data that relate target response to damage processes (penetration, blast effects, etc.) in terms of mission performance factors.

Explanatory Notes: The "damage/kill criteria" subfield contains those terms which are used to describe the levels of threat-induced damage required to effect various levels of aircraft kill. Hence, the term "damage/kill criteria" is used to represent that collection of data that identifies, as a function of damage processes, those critical components, subsystems, and systems which, if damaged or destroyed, will yield defined aircraft kill levels. This data base, in effect, synthesizes the physical response of target elements and the net effect of this response on the mission accomplishment or mission performance of the aircraft. The subdivision of "damage/kill criteria" is shown below.



5.3.2.1.1 Subfield Term: Damage and Failure Modes

Definition: A description that relates the response of a target or target element to assumed levels of damage.

Explanatory Notes: The term "damage and failure modes" is used to represent that collection of data which taken together describes the inherent susceptibility of a target to damage which results in a performance degradation, loss of function, or similar effect. In general, damage and failure modes are independent of specific threat types but relate to assumed levels of damage attributable to damage processes. The response of the target can be measured (or stated) at the component, subsystem, or system level. An example of damage and failure modes for a hypothetical dual hydraulic system is shown below:

Assumed Damage Level	Component Level Response	Subsystem Level Response	System Level Response
Penetration of Hydraulic Reservoir, Line, etc.	Loss of Primary System Hydraulic Fluid	Loss of Primary Hyd. Sys.	50% Reduction In Roll Rate

5.3.2.1.1-1 Aerodynamic Damage - Damage which adversely affects the aerodynamic qualities of the aircraft. Aerodynamic damage includes:

1. Damage which is the result of progressive skin peeling

2. Damage-induced flutter

3. Damage resulting in a degradation or loss of control, decrease of speed and/or altitude.

5.3.2.1.1-2 Critical Components - Those aircraft components which, if damaged or destroyed, would yield a defined or definable aircraft kill level.

5.3.2.1.1-3 Flight Essential Functions - Those subsystem functions required to enable an aircraft to sustain controlled flight with qualities of no less than level 3 as defined by MIL-F-8785 or MIL-F-83300 for the given classifications of aircraft or by MIL-H-8501.

5.3.2.1.1-4 Mission Essential Functions - Those subsystem functions required to enable an aircraft to perform its designated mission(s).

5.3.2.1.1-5 Damage Mode - A particular form, variety, state, condition, or configuration of damage upon a portion or element of an aircraft system.

5.3.2.1.1-6 Damage Mode and Effects Analysis - The analysis of an aircraft system conducted to determine the flight and mission essential components, extent of damage sustained from given levels of hostile weapon damage mechanisms (nonnuclear, or high energy lasers), and the effects of such damage modes on the continued controlled flight and mission completion capabilities of the aircraft system.

5.3.2.1.1-7 Failure Mode - A subset of damage modes characterized by damage resulting in functional degradation of the system or system element beyond an allowable limit.

5.3.2.1.1-8 Failure Mode and Effects Analysis (FMEA) - A systematic, quantified determination of the probabilities and severities of component, subsystem and system failures based upon assumed levels of damage and the system operating as an integral part of the aircraft.

5.3.2.1.1-9 Failure Threshold - The minimum level of weapon effects that is capable of causing the failure or malfunction of an aircraft material, component, or system.

5.3.2.1.1-10 <u>Primary Damage Effects</u> - Damage directly resulting from damage processes. Examples of "primary damage effects" are incendiary caused fire, control linkage severance, etc.

5.3.2.1.1-11 <u>Secondary Damage Effects</u> - Damage indirectly caused by the interaction of a damage process with a component, subsystem, or system. Examples of "secondary damage effects" are fire which results from a penetrator-caused fuel leakage contacting a hot surface, control linkage jamming due to blast-induced buckled skin panels, etc.

5.3.2.1.2 Subfield Term: Materials Response

Definition: The reaction of target materials when subjected to damage processes.

Explanatory Notes: The term "materials response" represents the characteristics and reaction of aircraft materials impacted or impinged upon by damage mechanisms. The characteristics of these materials under such conditions are revealed by such descriptors as damage tolerance, fracture toughness, impact resistance, ballistic limit, etc. The reactions of the material can be described by cracking, delamination, spalling, petalling, punching, etc.

5.3.2.1.2-1 Spalling - The detachment or delamination of a layer of material in the area surrounding the location of impact with the damage process. "Spalling" can occur on both the front and rear surfaces.

5.3.2.1.2-2 Attached Spall - Delaminations that remain attached around the periphery of the hole or spall area. The delamination may remain nearly in its original position or may be subjected to various degrees of rotation. One basic characteristic of "attached spall" is that the impact face lamina remain in their pre-impact location.

5.3.2.1.2-3 Chunk Spall - Damage of the type resulting in spall and petal spall where the thickness and at least one orthogonal directional dimension are approximately the same.

5.3.2.1.2-4 Terrace Spall - A spall pattern where the area of successive spall layers increases in a series of steps, progressing from front to exit face within the target.

5.3.2.1.2-5 Crack - A complete cleavage and separation of original target material along planes more or less perpendicular to the original target surface.

5.3.2.1.2-6 Petalling - Plastic deformation of a ductile material when struck by an impacting projectile or fragment, resulting in material being forced outward in leaflike or petal forms.

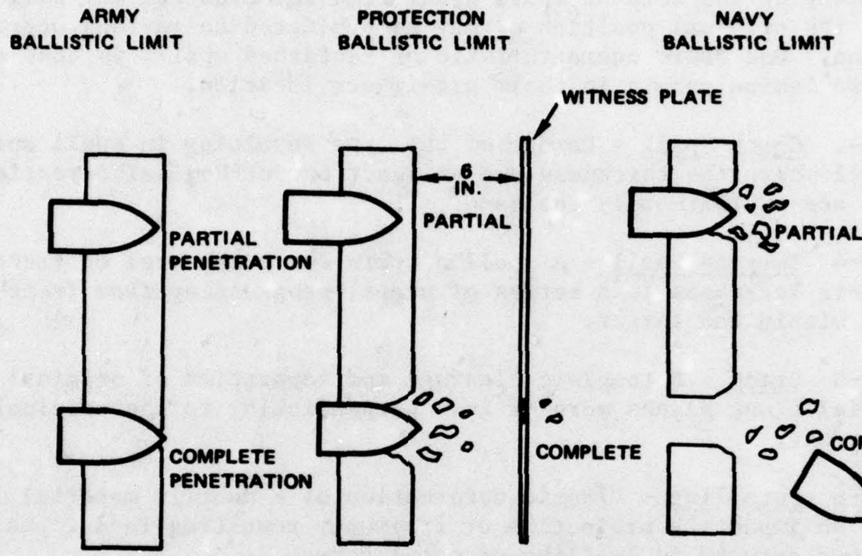
5.3.2.1.2-7 Punching - A material failure in shear evidenced by a circular plug the presented size of the attacking projectile or fragment being forced out of the material.

5.3.2.1.2-8 Perforation - The formation of a hole or holes in material struck by an impacting projectile or fragment. A portion of the material is accelerated ahead of the projectile or fragment and exits at the rear as a plug or as a number of secondary fragments.

5.3.2.1.2-9 Ballistic Resistance - A measure of the capability of a material or component to stop or reduce the impact velocity and mass of an impacting projectile or fragment.

5.3.2.1.2-10 Ballistic Limit - The average of two striking velocities, one of which is the highest velocity giving a partial penetration and the other of which is the lowest velocity giving a complete penetration. There are several measures used in rating the resistance of armor or other materials to penetration, the three most widely used criteria are: (1) the Army, (2) "protection", and (3) the Navy ballistic limits. The essential difference between these tests is the difference in the criterion employed to define a perforation as illustrated. In the past, testing was performed using the Army or the Navy criterion for defining

penetration, while the most recent firings have emphasized the protection criterion. See definitions 5.6.1-6, 5.6.1-7, and 5.6.1-8 for more information regarding protection ballistic limit tests.



5.3.2.1.2-11 <u>V_X Ballistic Limit</u> - Any expression of ballistic limit wherein the "X" subscript denotes probability of complete penetration for a projectile or fragment of striking velocity "V". The most commonly used V_X ballistic limit is V50 which is the critical velocity at which 50% complete penetrations and 50% partial penetrations of the target material can be expected.

5.3.2.1.2-12 <u>Impact Fracture</u> - Catastrophic fracture upon impact of penetrator.

5.3.2.1.2-13 <u>Melting</u> - The primary response of metal materials subjected to a HEL is to become extremely hot due to the thermal energy generated in them by the HEL beam and to then melt out of the beam path. The depth of the melt is dependent upon the time increment the beam is placed on the target.

5.3.2.1.3 Subfield Term: Subsystem Response

Definition: The reaction of target subsystems when subjected to damage processes.

Explanatory Notes: The "subsystem response" subfield is generally used to represent subsystem reactions to threat impingement such as leakage rate, leak path, damage effects (both primary and secondary), progressive damage, electrical short circuits, limited movement of control surfaces, fuel starvation, alternate operating mode, etc.

5.3.2.1.3-1 <u>Leakage</u> - The accidental escape of fluid from a system which is caused by damage processes.

5.3.2.1.3-2 <u>Leak Rate</u> - The speed or rate-of-flow of the accidental escape of fluid from a system which is caused by damage processes. The leak rate is influenced by such factors as the hole size, internal/external pressure, fluid level, etc.

5.3.2.1.3-3 <u>Leakage Path</u> - The route, direction, or course taken by the accidental escape of fluid from a system which is caused by damage processes.

5.3.2.1.4 Subfield Term: Personnel Response

Definition: The reaction of aircrew personnel when subjected to damage processes.

Explanatory Notes: "Personnel response" includes discomfort, incapacitation, or fatality that may be experienced from exposure to primary or secondary damage effects. The primary effects include penetration (by projectiles, fragments, or spallation), high-explosive blast effects, and exposure to chemical agents. Secondary effects are those created by primary damage effects and include such factors as loss of pressurization, breathing oxygen, cooling, or ventilation, and the presence of fire, toxic gases, and smoke.

5.3.2.2 Subfield Term: Physical Descriptors

Definition: Quantitative measures of the physical properties of the target or target element.

Explanatory Notes: These measures include such descriptive information as presented area, inherent shielding, component material, material thickness, etc. This information is required ultimately to determine vulnerable areas, penetration probabilities, residual velocities, etc., that are used in an aircraft vulnerability assessment.

5.3.2.2-1 Presented Area (Ap) - The area of a target or target element projected on a plane perpendicular to the attack aspect (i.e., shot line).

5.3.2.2-2 Inherent Shielding - The amount of shielding a component possesses due to its location within the airframe. Normally, this shielding is measured along a shot line in terms of equivalent inches of aluminum in order to facilitate penetration computations.

5.3.2.2-3 Skin-to-Component Distance - The minimum distance between the aircraft outer skin and a component of interest. Normally, this distance is measured along a shot line normal to one of the six cardinal aircraft aspects (i.e., front, side, top, bottom, etc.).

5.3.2.3 Subfield Term: Subsystem Descriptors

Definition: Descriptions or identifications relating to the type, nature, use, operating conditions and limitations of the subsystems which comprise the target or target element.

Explanatory Notes: These descriptors are terms or data which, in some manner, relate to or influence the damage susceptibility of subsystems. Terms or data descriptive of the operating temperature, pressure, or other factors useful in describing the vulnerability nature of the target are included. Examples are fly-by-wire flight control system, integral fuel tanks, emergency/back-up system, triple-redundant control linkage, high-airflow propulsion unit, etc.

5.3.2.3-1 Pyrophoric Fuel - A fuel which ignites spontaneously in air. Examples of this type fuel are high-energy fuels for jet airplanes and propellants for missiles.

5.3.2.3-2 Lean Limit - A fuel-air concentration where there is insufficient fuel to support combustion.

5.3.2.3-3 Rich Limit - A fuel-air concentration where there is an excess of fuel to support combustion.

5.3.2.3-4 Power-Booster Flight Control System - A reversible control system in which pilot effort is exerted through a mechanical linkage and, at some point, is boosted by a power source (usually hydraulic). The response for this type system is the same as the mechanical system for the linkage portion.

5.3.2.3-5 Mechanical Flight Control System - A flight control system which consists of a reversible mechanical linkage between the pilot and control surface.

5.3.2.3-6 Full Power Flight Control System - An irreversible control system in which the pilot actuates a power-control servo-mechanism, through a mechanical linkage or electrical, hydraulic, or pneumatic system, which positions the aircraft control surfaces.

5.3.2.3-7 Fly-By-Wire Flight Control System - A full-power flight control system employing an electrical control system rather than mechanical linkage.

5.3.2.3-8 Primary Structure - Elements of the aircraft, subsystems, etc., which provide the load paths for maintaining the basic structural integrity of the aircraft. Damage to any of these elements which would disrupt or sever any of the primary load paths could result in a catastrophic kill on the aircraft. Lesser damage to these elements would degrade the aircraft capability and could also lead to a catastrophic kill resulting from the secondary damage effects.

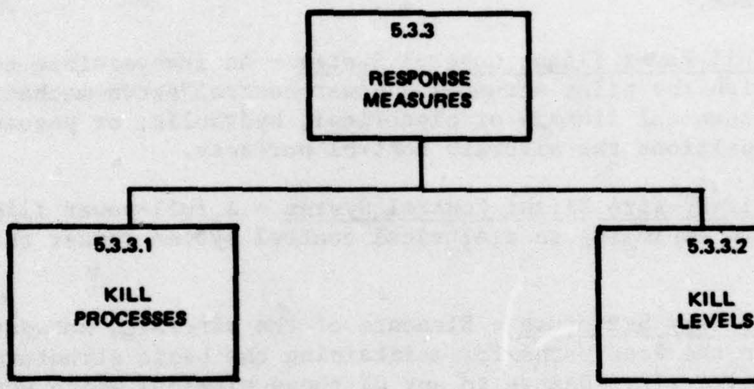
5.3.2.3-9 Secondary Structure - Elements of the aircraft, subsystems, etc., which provide the load paths for supporting ancillary equipment on the aircraft. Damage to any of these elements would degrade the capability of the aircraft and could also lead to a catastrophic kill resulting from secondary damage effects.

5.3.2.3-10 Nonhomogeneous Component - A component that is not constructed primarily of one material, but instead is made of a combination of materials of differing density and type. Examples are wiring bundles, avionics modules and flexible hydraulic lines.

5.3.3 Subfield Term: Response Measures

Definition: Qualitative and quantitative measures of the reaction, in terms of mission performance factors, of a target or target element from exposure to damage processes.

Explanatory Notes: Response measures are used to define the result of the interaction between threat mechanisms and an aircraft target. This definition includes both an identification of the nature of the damage, i.e., kill process, as well as the resultant aircraft response. This response or result is usually measured in terms of mission performance factors such as immediate loss, loss in ten minutes, etc. (i.e., kill levels). "Response measures" is subdivided as shown below.



5.3.3.1 Subfield Term: Kill Processes

Definition: The reaction and interaction between damage processes and the target or target element which result in mission performance degradation.

Explanatory Notes: The term "kill processes" refers to the nature of the damage that results in a definable performance degradation. The difference between the terms "kill processes" and "damage processes" is whether a mission performance degradation results from the damage process. Therefore a kill process is a subset of a damage process. For example, blast effects may or may not have a detrimental effect on mission performance. If they have a detrimental effect, blast effects would constitute a kill process; if not, blast effects would not constitute a kill process.

5.3.3.1-1 Direct Kill Process - The failure or degradation of a target or target element caused by direct interaction with a damage process.

5.3.3.1-2 Indirect Kill Process - The failure or degradation of a target element which results from a damaging or degrading condition on another target element by a direct interaction with damage process. An example of an "indirect kill process" is: the loss of a flight control hydraulic system by action of a fuel leakage fire initiated by an incendiary projectile impact.

5.3.3.1-3 Explosive Disintegration - Sudden rupture and destruction of components due to high-pressure of gas or vapor within the components. This disintegration may occur as a result of high-temperature or fire conditions causing excessive internal pressure buildup, or where highly-pressurized gaseous containers are struck by a projectile or fragment.

5.3.3.2 Subfield Term: Kill Levels

Definition: Measures of the degree to which a target or target element suffers performance degradation due to damage processes.

Explanatory Notes: The specification form of "kill levels" will vary, depending on the particular application, aircraft type, etc. Hence, a number of criteria have been developed to measure the degree of performance degradation. These criteria may be applied to the total aircraft or to individual subsystems. Examples of aircraft kill levels include time-based attrition scales (e.g., K kill - loss of aircraft within 30 seconds, A kill - loss of aircraft within 5 minutes, etc.) as well as mission-limiting measures such as mission abort, mission available, mission completion, etc. In general, there are two categories of kill levels: inclusive and exclusive. The requirements for inclusive kill levels are defined so that each kill level is a subset of any less demanding kill level. For example, K kill is a subset of A kill. Exclusive kill levels are defined in such a way that the requirements for achieving one kill level are completely independent of the requirements for achieving another level.

5.3.3.2-1 Attrition Kill - A measure of the degree of aircraft damage which renders it incapable of being repaired, or not economical to repair, so that it is lost from the inventory. Examples of attrition kill levels that have been used are:

1. KK-kill - damage that will cause an aircraft to disintegrate immediately upon being hit.

2. K-kill - damage that will cause an aircraft to fall out of manned control within 30 seconds after being hit.

3. A-kill - damage that causes an aircraft to fall out of manned control within 5 minutes after being hit.

4. B-kill - damage that causes an aircraft to fall out of manned control within 30 minutes after being hit.

5. C-kill - damage that causes an aircraft to fall out of manned control before completing its designated mission. (This type of attrition kill is also commonly referred to as a "Mission Kill.")

5.3.3.2-2 Catastrophic Kill - A measure of the degree of aircraft damage which causes it to disintegrate immediately after the damage is inflicted. This type of kill is generally referred to as a KK-kill. See explanatory notes under "Attrition Kill."

5.3.3.2-3 Mission Available Kill - A measure of a degree of aircraft damage which does not prevent the aircraft from completing its designated mission, but necessitates repairs before the next scheduled mission.

5.3.3.2-4 Mission Abort Kill - A measure of the degree of aircraft damage which prevents the aircraft from completing its designated mission, but is not sufficient to cause a loss of the aircraft to the inventory.

5.3.3.2-5 Forced Landing Kill - A helicopter kill category in which damage to the helicopter or a warning indication causes the pilot to land, powered or unpowered. The extent of damage may be such that very little repair is required to fly the helicopter back to base; however, if the pilot continues to fly, the aircraft will be destroyed. The forced landing kill category includes a forced landing at any time after damage occurs but before the expenditure of the aircraft fuel load.

5.3.3.2-6 Repair Time Kill - A measure of the degree of aircraft damage which will be sufficient to cause the aircraft to miss its next scheduled mission.

5.3.3.2-7 Mission Limiting Condition - A measure of a degree of aircraft damage which prevents an aircraft from completing a portion of its assigned mission. An example would be the loss of one engine on a supersonic fighter, which would inhibit its ability to engage supersonic targets.

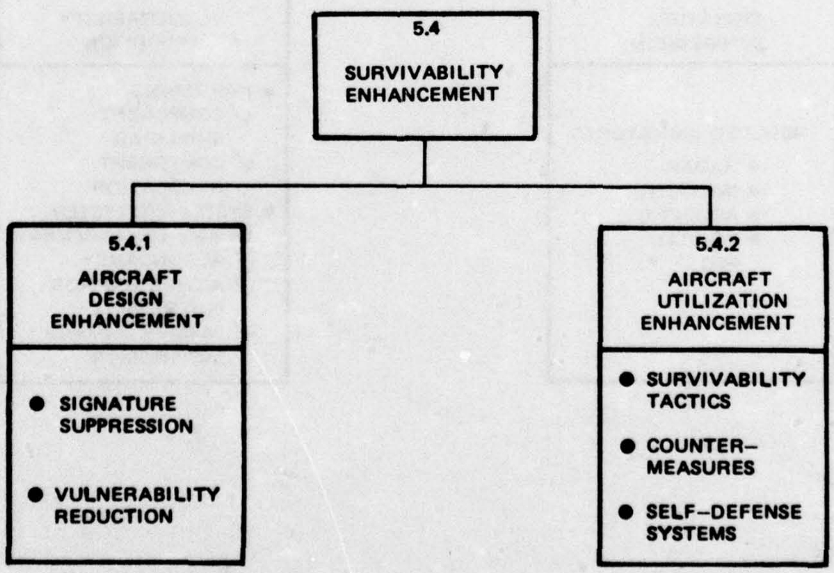
5.3.3.2-8 E-Kill - A measure of the degree of damage that will cause an aircraft to be structurally damaged upon landing given it survives to the point of landing (e.g., a tire blown).

5.3.3.2-9 V-Kill - A measure of the degree of damage that will cause a vertical takeoff or landing (VTOL) aircraft to be incapable of vertical flight, vertical takeoff, or vertical landing.

5.4 Topical Field Term: Survivability Enhancement

Definition: The use of any tactic, technique, or survivability equipment, or combination of techniques that increases the probability of survival of an aircraft when operating in a man-made hostile environment.

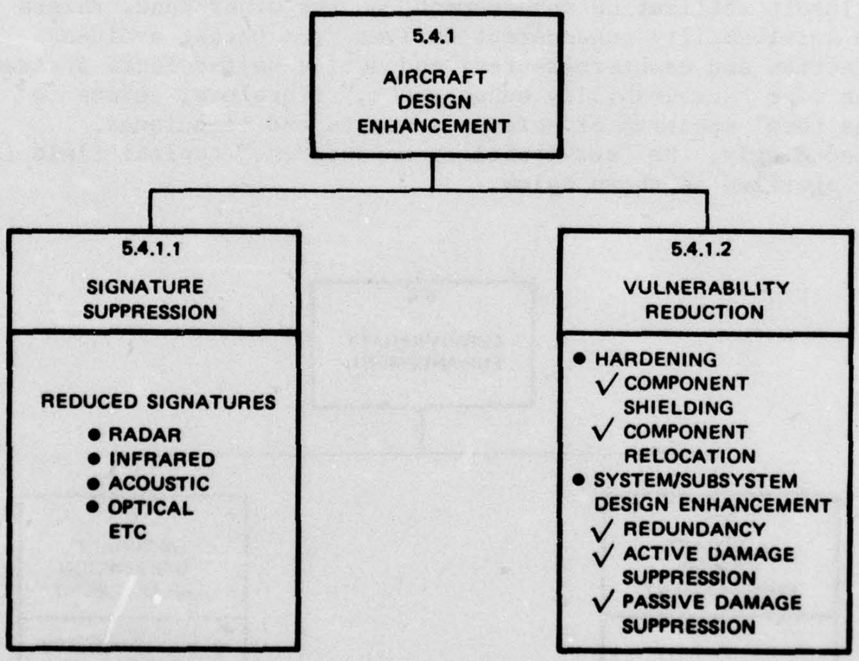
Explanatory Notes: Aircraft survivability enhancement can be accomplished by (1) reducing the damage susceptibility of the aircraft given an exposure to threat mechanisms and (2) reducing the probability of an exposure to threat mechanisms. In practice, these two objectives can be achieved through either aircraft design enhancement or aircraft utilization enhancement. Aircraft design enhancement refers to the increase of aircraft survivability by a reduction in signature (IR, radar, visual) and in vulnerability (e.g., armoring). Aircraft utilization enhancement, on the other hand, refers to survivability enhancement derived from threat avoidance (tactics and countermeasures) and active self-defense systems. The term "survivability enhancement," therefore, refers to the total spectrum of defense concepts and techniques. Accordingly, the "survivability enhancement" topical field is categorized as shown below.



5.4.1 Subfield Term: Aircraft Design Enhancement

Definition: Enhancement made inherent to the vehicle itself that tends to reduce detectability and vulnerability.

Explanatory Notes: The term "aircraft design enhancement" represents those design activities and elements directed toward increasing aircraft survivability. It does not include those elements and activities that are related to survivability enhancement derived from threat-degrading subsystem functions (e.g., ECM) or from the ways that the aircraft can be utilized in a hostile environment. These elements are included under "aircraft utilization enhancement". Accordingly, "aircraft design enhancement" is subdivided as shown below.



5.4.1.1 Subfield Term: Signature Suppression

Definition: The use of techniques that reduce the target aircraft signatures (i.e., infrared, radar, visual, etc.) that are used for guidance by a man-made threat mechanism.

Explanatory Notes: The term "signature suppression" represents that collection of terms that describe techniques or methods used to reduce aircraft inherent detectability. Signature suppression can be effected by basic design (e.g., shape) or by add-on materials such as radar absorbent material. This reduction in detectability can benefit survivability by inducing a delay in the threat's reaction or response time (e.g., shorter AAA open-fire ranges and hence fewer shots fired) or by completely denying the enemy knowledge of the aircraft's position. Synonyms for this term are "reduction of observables", "reduction of detectables", and "signature reduction."

5.4.1.1-1 Observables - Detectable emissions from an aircraft, such as radar, infrared, smoke, acoustical, optical, and ultraviolet characteristics.

5.4.1.1-2 Radar-Absorbent Material - Materials used to reduce aircraft radar cross sections by attenuating and minimizing reflections of incident energy.

5.4.1.1-3 Radar Cross-Section Reduction - Techniques and devices such as radar-absorbent materials and radar camouflage designed to reduce the radar signature of aircraft.

5.4.1.1-4 Infrared Radiation - Electromagnetic radiation in the 0.7 to 300 micron band. Infrared radiation may be used to locate and identify a target and point, track, and guide a missile to that target.

5.4.1.1-5 Infrared Signature - The amplitude, bandwidth, and modulation of a signal emitting or reflecting energy in the 0.7 to 300 micron band. This includes radiation from hot engine parts, gas exhaust, ram air temperature rise and other aircraft hot spots. It also includes solar reflections.

5.4.1.1-6 Infrared Suppressors -

1. Passive - shielding or ducting which precludes direct line-of-sight between missile detectors and hot metal on the aircraft.

2. Active - active suppressors cool down engine exhaust gases by mixing with ducted external air so that the resultant temperature levels are more difficult to detect.

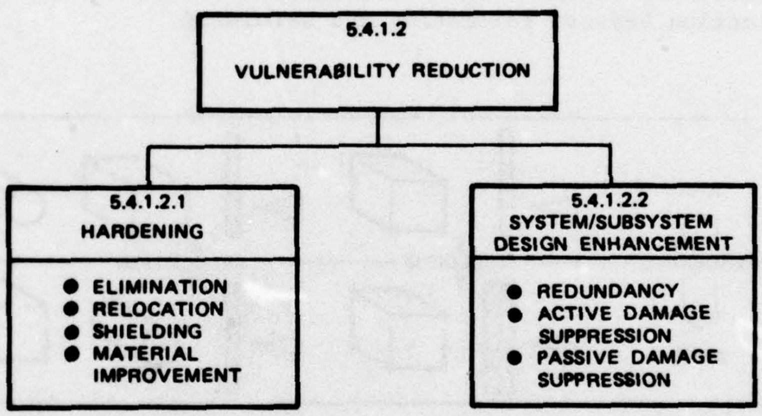
5.4.1.1-7 Acoustic Suppression - Refers to engine mufflers, sound absorbent materials, redesigned (or increased numbers of) rotor blades, etc., to reduce the noise produced by an aircraft in the audible range.

5.4.1.1-8 Visual Suppression (Glint, Glare) - Nonreflective paints and coating for structure and glass, redesigned (flat plate) canopies and camouflage paints. In the future this may include lighting techniques to reduce visual contrast.

5.4.1.2 Subfield Term: Vulnerability Reduction

Definition: Any technique that enhances the aircraft design in a manner that reduces the aircraft's susceptibility to damage when subjected to threat mechanisms.

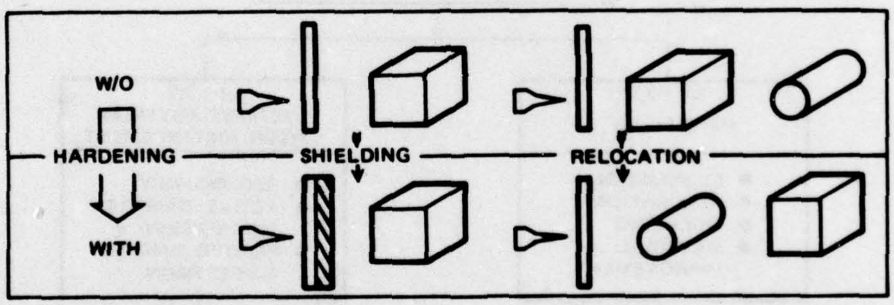
Explanatory Notes: The term "vulnerability reduction" refers to those activities and elements that are designed to reduce inherent aircraft vulnerability. A synonym for this term is "vulnerability minimization" which affirms that the enhancement considerations are also an integral part of the initial aircraft design process. Vulnerability reduction can be achieved from hardening (e.g., armor) or from subsystem design enhancement (e.g., redundancy). Accordingly, "vulnerability reduction" is subdivided as shown below.



5.4.1.2.1 Subfield Term: Hardening

Definition: That type of vulnerability reduction effected by interposing less essential components between critical components and the threat mechanisms, by eliminating critical components, or by the use of materials having improved characteristics.

Explanatory Notes: The term "hardening" is restricted solely to vulnerability reduction, and, further, solely to reductions achieved by eliminating critical components, relocating critical components to less vulnerable positions, physically shielding critical components with an armor-type material, or improving the materials' characteristics, e.g., strength ductility, reflectivity, etc. Accordingly, "hardening" has been subdivided into "elimination", "relocation", "shielding", and "material improvement". The schematic illustrates the distinction between relocation and shielding.



5.4.1.2.1.1 Subfield Term: Component Elimination

Definition: That type of hardening that is achieved by removal of a critical component.

5.4.1.2.1.2 Subfield Term: Component Relocation

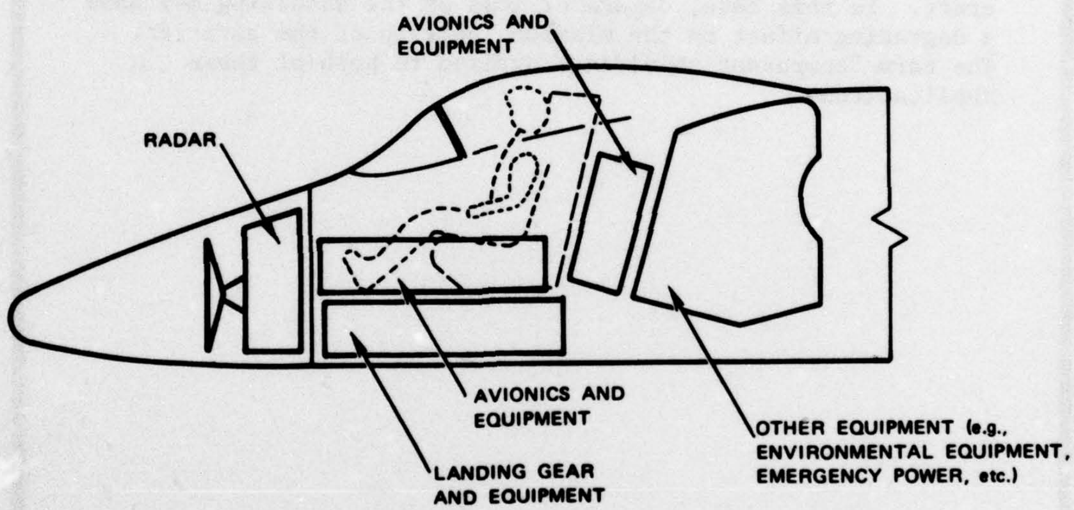
Definition: That type of hardening that is achieved by repositioning critical components in a manner that reduces the probability that a damage process will produce lethal damage.

Explanatory Notes: The term "component relocation" refers to those repositioning techniques or design actions that are used to (1) enhance component shielding by taking advantage of shielding offered by less critical components, (2) reduce the vulnerability of interdependent components, and (3) ensure that redundant components are sufficiently separated to maintain true single-hit redundancy.

5.4.1.2.1.2-1 Component Separation - The technique of locating or routing duplicate (redundant) system elements independently or the repositioning of critical interdependent components to prevent or minimize simultaneous damage from threat mechanisms.

5.4.1.2.1.2-2 Component Concentration - The technique of compactly grouping critical components to reduce the overall vulnerable area of vehicle subsystems so that they may be more effectively shielded, or located to present the least vulnerable aspect to a threat mechanism.

5.4.1.2.1.2-3 Protective Masking - The protection of a critical system component (as the pilot) by positioning less critical components between it and potential hostile fire. The figure illustrates pilot protection by masking techniques.



5.4.1.2.1.3 Subfield Term: Component Shielding

Definition: That type of hardening that is achieved with the use of plates, coatings, or other materials that tend to resist or absorb damage processes.

Explanatory Notes: The shielding material may or may not be an integral or load-bearing part of the aircraft structure. It may be parasitic in the sense that it is attached to bulkheads, frames, etc., and therefore serves only a shielding function. In this case, damage to or loss of the shielding would not necessarily cause a degrading condition on the aircraft. Integral shielding, on the other hand, may be constructed and installed as a load-carrying member of the aircraft. In this case, damage or loss of the shielding may have a degrading effect on the mission function of the aircraft. The term "component shielding" applies to both of these applications.

5.4.1.2.1.3-1 Armor - A shielding material provided for ballistic defeat of projectiles or fragments when inherent shielding is inadequate.

5.4.1.2.1.3-2 Armor Material - A basic material having those properties required to provide a measure of protection against ballistic impacts.

5.4.1.2.1.3-3 Armor System - A combination of one or more elements made of basic armor material(s) to form an effective ballistic-protection device.

5.4.1.2.1.3-4 Homogeneous Armor - An armor made from a single material that is consistent throughout in terms of chemical composition, physical properties, and degree of hardness.

5.4.1.2.1.3-5 Composite Armor - An armor system consisting of two or more different armor materials bonded together to form a protective unit.

5.4.1.2.1.3-6 Solid Armor - All homogeneous and composite armor materials and systems having no air spaces between elements.

5.4.1.2.1.3-7 Spaced Armor - Armor systems having spaces between armor elements.

5.4.1.2.1.3-8 Transparent Armor - Armor resulting from the lamination of commercially available hard glass, tempered glass, chemically-strengthened glass, polyurethanes, methal methacrylates and polycarbonates.

5.4.1.2.1.3-9 Integral Armor - Armor material used as a part of airframe or component construction to perform a load-carrying or other operational function, in addition to ballistic protection.

5.4.1.2.1.3-10 Parasitic Armor - Armor attached to an aircraft where the armor serves the sole function of giving ballistic protection.

5.4.1.2.1.3-11 Convertible Armor - Basic aircraft structure in combination with selected lightweight armor materials that could be easily installed or "buttoned on" an aircraft depending on mission requirements.

5.4.1.2.1.3-12 Impact Overmatch Armor Material - A term, used primarily in association with steel armor, which indicates that the diameter of the impacting projectile is larger than the thickness of the armor plate.

5.4.1.2.1.3-13 Impact Undermatch Armor Material - A term, used primarily in association with steel armor, which indicates that the diameter of the impacting projectile is less than the thickness of the armor plate.

5.4.1.2.1.3-14 Full Multi-hit Capability - The ability of an armor to sustain two or more hits within a distance of three calibers without loss in ballistic performance.

5.4.1.2.1.3-15 Limited Multi-hit Capability - A lesser degree of armor protective ability than that provided by armor having full multi-hit capability.

5.4.1.2.1.3-16 Armor Material Merit Rating - The protection capability of candidate armor material related to the known protection capability of a standard steel armor. Normally, this rating is made on the basis of weight for the same ballistic protection level or in terms of ballistic protection level for the same areal density.

5.4.1.2.1.3-17 Rachel Net - A type of net mesh used in aircrew personnel equipment to provide maximum mobility and comfort. It is used to distribute the load of personnel armor over large areas of the torso.

5.4.1.2.1.3-18 Tension Web System - A web system that integrates rachel net with other fabric elements of a body armor suspension system.

5.4.1.2.1.3-19 Areal Density - A measure of the weight per unit area of armor material. It is expressed in pounds per square foot of area.

5.4.1.2.1.4 Subfield Term: Component Material Improvement

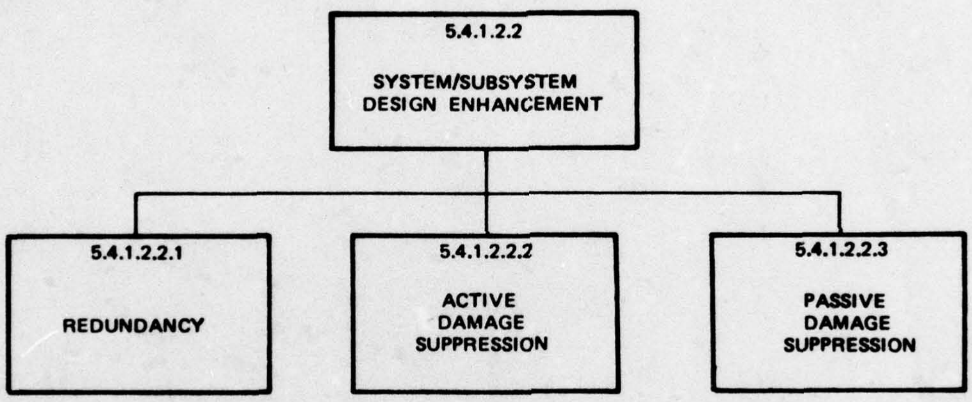
Definition: The type of hardening achieved by improving material characteristics that reduces the probability that a damage process will produce lethal damage.

Explanatory Notes: The term "component material improvement" refers to the continuing research and development of new or improved materials which can replace existing component material to reduce the vulnerability of the component or underlying components to a threat mechanism. An example would be the replacement of a transmission's steel housing with a steel-titanium alloy which is more impervious to ballistic or HEL penetration.

5.4.1.2.2 Subfield Term: System/Subsystem Design Enhancement

Definition: Any type of vulnerability reduction, exclusive of hardening, that is effected in the design of a system or subsystem.

Explanatory Notes: The term "system/subsystem design enhancement" refers to all techniques, methods, and design actions used to reduce the inherent vulnerability of a system or subsystem. These techniques consist of both active and passive damage suppression (e.g., fire suppression/extinguishing systems vs reticulated foam) as well as design redundancy. Accordingly, "system/subsystem design enhancement" is subdivided as shown below.



5.4.1.2.2.1 Subfield Term: Redundancy

Definition: The employment of multiple devices, structural elements, parts, or mechanisms in combination for the purpose of enhancing survivability.

Explanatory Notes: Redundancy can be employed at the component, subsystem, or system level. The extent of redundancy may be of two general types: (1) total redundancy, in which each redundant element is fully capable of performing the required function, or (2) partial redundancy, in which each element independently performs some percentage of the total function. The difference between these modes of redundancy is in their response to threat-induced damage. For example, the loss of one channel of a totally redundant flight control system will have no detrimental effects on flight control performance. On the other hand, the loss of one channel on a partially redundant flight control system may restrict the flight envelope of the aircraft.

5.4.1.2.2.1-1 Actual Redundancy - The redundancy achieved through the use of similar sets of components, elements, or mechanisms in which each set performs identical functions. Examples of "actual redundancy" are: two identical actuators to move the same control surface, two identical fuel pumps to supply engine fuel, etc.

5.4.1.2.2.1-2 Functional Redundancy - The redundancy achieved through the use of different sets of components elements, or mechanisms in which each set can perform identical functions. Examples of "functional redundancy" are: redundant roll control through ailerons or flaperons, electrical backup to mechanical linkage from the control stick to a servo actuator, etc.

5.4.1.2.2.2 Subfield Term: Active Damage Suppression

Definition: Any design technique that reduces vulnerability by incorporating a sensor or other device which, upon the impingement of a threat mechanism, activates a function that tends to contain the damage (i.e., reduce or negate subsequent effects) and thus reduces the probability that the impingement will lead to the disablement of the system or subsystem.

Explanatory Notes: Active damage suppression techniques are designed to activate after threat impact and, therefore, make use of a sensor(s) as well as a suppressive device. For example, a fire detection/extinguishing system uses a heat detector to sense high-temperature areas attributable to incendiaries, sparks, etc. Following detection the system may, depending upon the design, automatically dispense an inerting fluid or gas or may alert the pilot to the presence of a hazardous situation. At his option, then, the extinguishant may be released. These techniques can be contrasted to passive damage suppression techniques which operate independently of a sensing or threat assessment function.

5.4.1.2.2.2-1 <u>Fire Suppression System</u> - A method, device, or system to detect fire or ignition resulting from combat threat effects and to extinguish the fire in sufficient time to prevent aircraft structural damage.

5.4.1.2.2.2-2 <u>Explosion Suppression</u> - A method, device, or system to effectively extinguish an explosion after ignition but before the build-up of pressure to levels above the design limit of the fuel tank or other compartment subject to explosion.

5.4.1.2.2.3 Subfield Term: Passive Damage Suppression

Definition: Any design technique that reduces vulnerability by incorporating a substance which, after the impingement of a threat mechanism, tends to contain the damage (i.e., reduce or negate subsequent effects) and thus reduces the probability that the impingement will lead to the disablement of the system or subsystem.

Explanatory Notes: "Passive damage suppression" techniques are independent of sensing or assessing functions and, hence, are integral techniques whose response to threat impact serves to minimize damage. Examples of such techniques are polyurethane foam, which prevents internal tank explosion; continuous exhaust gas inerting, which eliminates combustible mixtures from inside fuel tanks; blowout panels, which reduce structural damage; and so forth. These techniques can be contrasted to active damage suppression techniques, which function only after sensing threat impact.

5.4.1.2.2.3-1 Leakage Control - A technique used to handle and direct liberated fluids or vapors in such a manner that danger to the aircraft and crew is minimized. This technique includes sealing of sensitive or ignition-producing areas, drainage provisions, flow diverters, and venting features.

5.4.1.2.2.3-2 Leakage Suppression - A technique that uses self-sealing materials designed to accept a degree of ballistic damage and seal the damaged area with little or no leakage from the fluid container.

5.4.1.2.2.3-3 Gelling Additive - A substance added to regular fuel which gelantizes and increases its viscosity, and reduces vaporization and susceptibility of the fuel to fire and explosion.

5.4.1.2.2.3-4 Coagulating Cell - A fuel cell containing a substance between the inner and outer layers of the tank structure which, when exposed by damage, causes the fuel to become a soft, semisolid mass or clot resulting in sealing.

5.4.1.2.2.3-5 - Fuel Tank Inerting - A method or system utilizing noncombustible gases such as nitrogen or freon to preclude combustible fuel and air mixtures, and thus prevent fire and explosion.

5.4.1.2.2.3-6 - Exhaust-Gas Inerting System - An inerting system which utilizes exhaust gas inside fuel tanks to reduce the oxygen concentration to levels that will not support combustion.

5.4.1.2.2.3-7 - Nitrogen Inerting System - An inerting system which utilizes nitrogen inside fuel tanks to reduce the oxygen concentration to levels that will not support combustion.

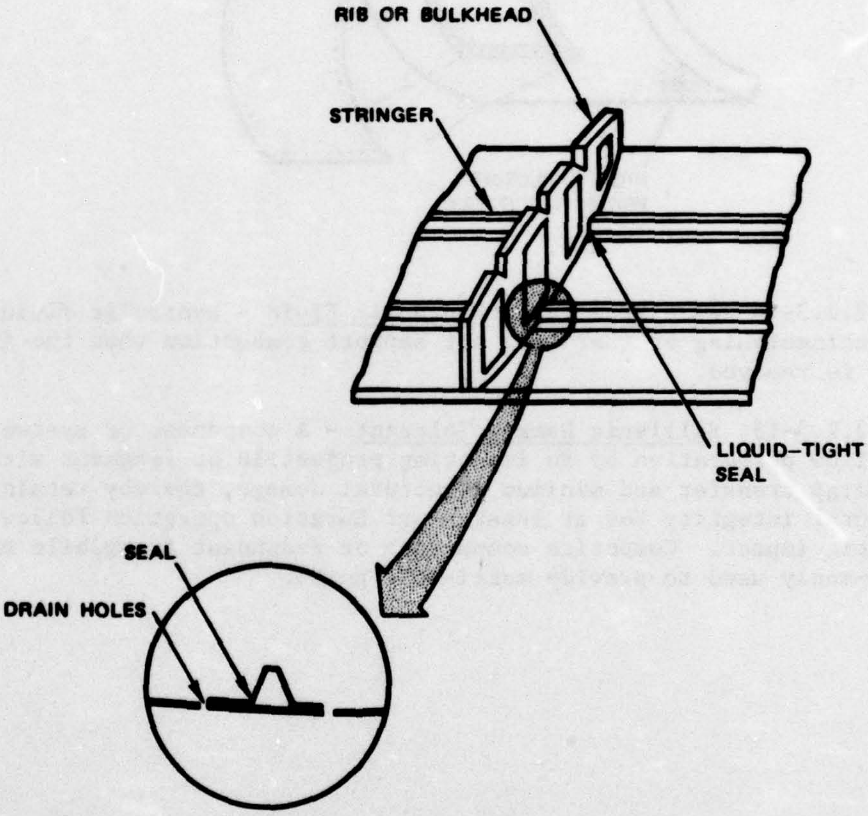
5.4.1.2.2.3-8 - Halon Inserting System - An inserting system which utilizes halon inside fuel tanks to reduce the oxygen concentration to levels that will not support combustion.

5.4.1.2.2.3-9 - Void Filler Foam - A spongelike polyurethane for filling voids around fuel cell exteriors and other airframe compartments in order to minimize the development of combustible mixtures from a fuel leakage.

5.4.1.2.2.3-10 - Reticulated Polyurethane Foam - A flexible polyurethane foam with a netlike porous structure used in fuel cell interiors to prevent fire and explosion. Two mechanisms by which reticulated foam is believed to suppress the combustion reaction are: (1) removal of energy from the combustion process by absorption of heat, (2) removal of energy from the combustion process by mechanical interference.

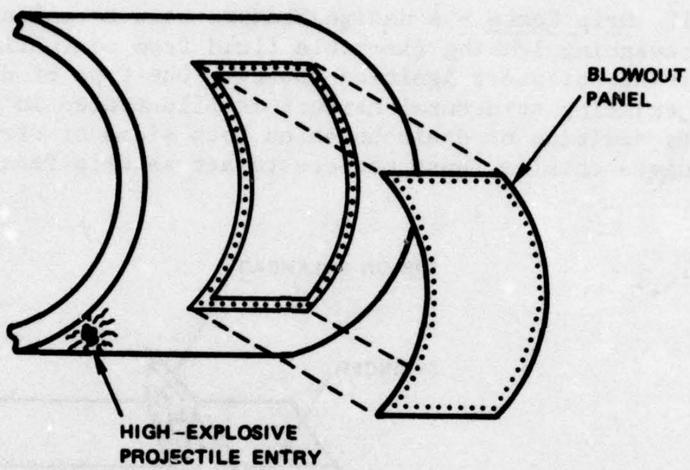
5.4.1.2.2.3-11 Whiffle Balls - Hollow, thin-shell polyethelene balls, with multiple perforations used for explosion and fire suppression in fuel tanks. The fuel capacity of a tank filled with these balls is reduced approximately 5%.

5.4.1.2.2.3-12 Drip Fence - A design feature used to enhance survivability by preventing leaking flammable fluid from contacting electrical equipment, wiring, or other ignition source. One type of drip fence that makes use of existing structural members is illustrated in the figure. In effect, the addition of drain holes on both sides of structural members such as stringers enables those members to act as drip fences.



Drip Fence Installation Making Use of Existing Structural Members.

5.4.1.2.2.3-13 Blowout Panel - A device used to minimize internal and primary structural damage resulting from high impulse pressures caused by internal blast. An example of a "blowout panel" is illustrated below.



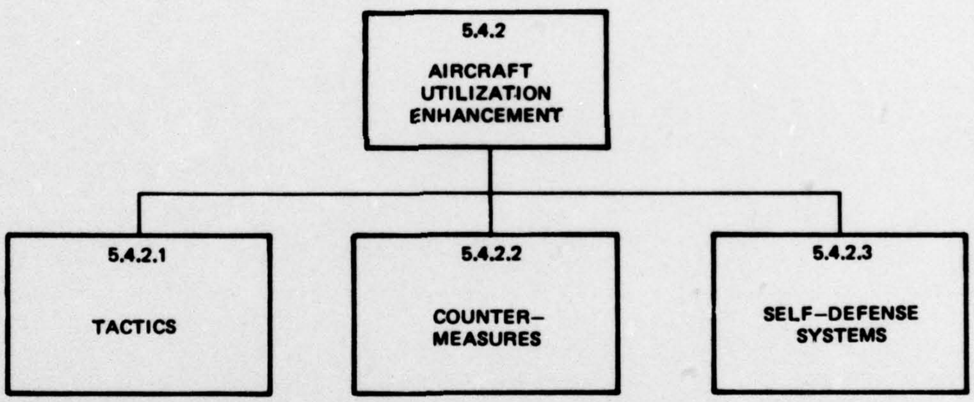
5.4.1.2.2.3-14 Fire Resistance Hydraulic Fluid - Hydraulic fluid that is self-extinguishing or that will not support combustion when the flame source is removed.

5.4.1.2.2.3-15 Ballistic Damage Tolerant - A component or system that will allow perforation by an impacting projectile or fragment with minimum energy transfer and minimum structural damage, thereby retaining structural integrity for at least short duration operation following ballistic impact. Composite components or redundant frangibile materials are commonly used to provide multi-load paths.

5.4.2 Subfield Term: Aircraft Utilization Enhancement

Definition: Survivability enhancement that derives either from threat-degrading system or subsystem functions or from the ways in which the aircraft can be utilized in a hostile environment.

Explanatory Notes: "Aircraft utilization enhancement" serves to reduce the probability of a hit and the expected number of impacts from a threat encounter. The term "aircraft utilization enhancement" represents those elements and activities that relate to tactics, countermeasures, and self-defense systems. These techniques can be contrasted to aircraft design enhancements that are made inherent to the aircraft itself and that tend to reduce inherent detectability/vulnerability. Accordingly, "aircraft utilization enhancement" is subdivided as shown below.



5.4.2.1 Subfield Term: Tactics

Definition: Methods of survivability enhancement that derive from the use of mission implementation techniques which are judiciously selected from the set of options provided by the aircraft in the context of the hostile environment and mission objectives.

Explanatory Notes: The term "tactics" is used to describe those activities, flight and mission planning, flight profiles, formations, etc., that are designed to minimize aircraft exposure to threats. These tactics exploit the aircraft's performance and weapon delivery capabilities with the objective of limiting threat response. Examples are high-speed, low-altitude penetration, jinking maneuvers, known threat site avoidance, standoff weapon delivery, nap-of-the-earth flight, and so forth.

5.4.2.1-1 Nap-of-the-Earth Flight - Flight (generally associated with helicopters) as close to the earth's surface as vegetation or obstacles will permit, while generally following the contours of the earth. Airspeed and altitude are varied as influenced by the terrain, weather, ambient light, and enemy situation.

5.4.2.1-2 Contour Flying - Flight at approximately a constant incremental altitude above the surface (terrain and vegetation) contour.

5.4.2.1-3 Jinking - Aircraft maneuvers (i.e., random changes in flight path, altitude, speed, etc.) designed to induce miss-producing effects on enemy-launched weapons.

5.4.2.1-4 Threat Avoidance - Flight-path selection designed to fly around the effective coverage of known threat locations in order to minimize threat encounters.

5.4.2.2 Subfield Term: Countermeasures

Definition: Any systems or subsystems which either (1) actively tend to degrade the ability of a threat to function in its normal mode or to achieve its normal level of effectiveness, or (2) provide information which enables the aircraft command to respond to the hostile environment in a manner that enhances survival.

Explanatory Notes: "Countermeasures" have been designed to operate in all three portions of the electromagnetic spectrum - RF, infrared, visual - and can be generally classified as active or passive. Active countermeasures operate on or directly influence enemy radiation or radiation reflections. Passive countermeasures do not directly influence enemy radiation but exploit it for survival enhancement purposes. For example, an active infrared countermeasure (IRCM) is the ejection of an infrared flare to cause an IR missile to home-on the flare instead of the aircraft. A passive IRCM is the detection of a missile booster flash by IR surveillance equipment to provide programming for ejecting flares at the most appropriate times. The term "countermeasures," therefore, describes the full spectrum of systems, subsystems, equipments, etc., that utilize the electromagnetic spectrum to degrade threat effectiveness.

5.4.2.2-1 Electronic Warfare (EW) - That division of the military use of electronics involving actions taken to prevent or reduce an enemy's effective use of radiated electromagnetic energy and actions taken to ensure our own effective use of radiated magnetic energy. Its primary objective is to enhance survivability in threat environments which utilizes the electromagnetic spectrum for searching, intercepting, and attacking friendly aircraft.

5.4.2.2-2 Electronic Countermeasures (ECM) - That major subdivision of electronic warfare involving actions taken to prevent or reduce the effectiveness of enemy equipment and tactics employing or affected by electromagnetic radiations and to exploit the enemy's use of such radiations.

5.4.2.2-3 Electronic Deception - The deliberate radiation, reradiation, alteration, absorption, or reflection of electromagnetic radiations in a manner intended to mislead an enemy in the interpretation of data received by his electronic equipment or to present false indication to electronic systems. There are two categories of deception: manipulated and imitative. Manipulative deception refers to the alteration or simulation of electromagnetic radiation to accomplish deception. Imitative deception refers to the introduction of radiations into enemy channels which imitate his own emissions.

5.4.2.2-4 Electronic Jamming - The deliberate radiation, reradiation, or reflection of electromagnetic signals with the object of impairing the use of electronic devices by the enemy.

5.4.2.2-5 Electronic Counter-Countermeasures (ECCM) - The major subdivision of electronic warfare involving actions taken to insure our own effective use of electromagnetic radiations despite the enemy's use of countermeasures.

5.4.2.2-6 Electronic Decoys - Devices deployed in electronic environments to confuse enemy radars or other acquisition and tracking systems in order to dilute enemy defense capabilities.

5.4.2.2-7 Radar Homing and Warning (RHAW) - Aircraft equipment used to provide signal recognition and real time awareness of defensive radar systems.

5.4.2.3 Subfield Term: Self-Defense Systems

Definition: Any system which tends to enhance survivability by providing a real-time method of either (1) destroying the threat propagator before initiation of the damage process or (2) damaging the threat control system to an extent which degrades its functioning.

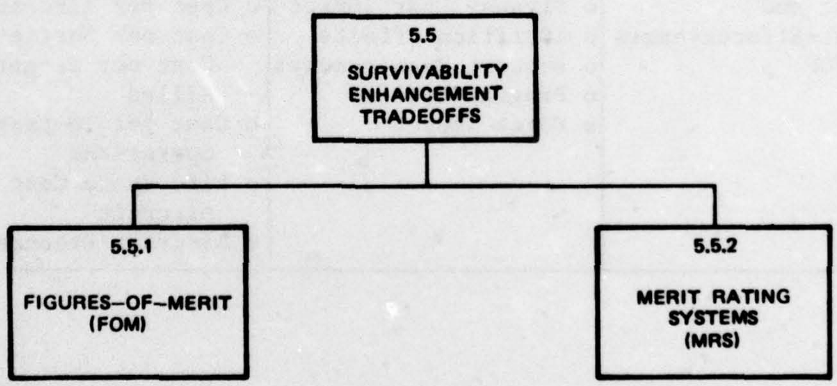
Explanatory Notes: The term "self-defense systems" describes those systems which destroy or degrade threat operations by actively intercepting the threat mechanism in flight or by destroying or damaging the threat prior to launch. Examples of active self-defense systems are: (1) a bomber defense missile (BDM) for damage to or destruction of airborne interceptors; and (2) a short-range attack missile (SRAM) for damage to or destruction of surface-based threats. "Self-defense systems" can be contrasted to active countermeasures, which relates to the use of portions of the electromagnetic spectrum to degrade threat effectiveness by jamming or deception. It is pointed out, according to the above definition, passive self-defense systems cannot be included under "self-defense systems". These systems are included under the subfields "tactics" and "countermeasures".

5.4.2.3-1 Active Self-Defense - A method of self-protection by use of armament to destroy the enemy threat or to suppress his activity so that he cannot fire or launch a weapon.

5.5 Topical Field Term: Survivability Enhancement Tradeoffs

Definition: The process of examining and quantifying both the survival benefits and the penalties associated with alternative survivability enhancement techniques of aircraft and subsystems; the objective of this tradeoff process is to derive the insights necessary to select the optimal configuration or utilization for defined mission roles.

Explanatory Notes: The topical field "survivability enhancement tradeoffs" addresses the benefits and penalties associated with aircraft utilization enhancement as well as with aircraft design enhancement. Therefore the procedures used to perform these tradeoffs should integrate penalties such as increased weight, reduced payload, reduced performance, increased cost, etc. with benefits measured in terms of increased probability of survival, reduced force requirements, reduced attrition cost, etc. The term "survivability enhancement tradeoffs" refers to those techniques, procedures, and activities that quantify and relate benefits and penalties. Therefore, this topical field contains terms that define both the benefits and penalties (figures-of-merit) and the procedures used to integrate the benefits and penalties (merit rating systems).



5.5.1 Subfield Term: Figures-of-Merit (FOM)

Definition: Parameters used to define the benefits and penalties associated with aircraft design or usage alternatives.

Explanatory Notes: The definition of a figure-of-merit involves the identification of the measure as well as the specification of the associated units or dimensions used with the measure. "Figures-of-merit" can be developed as measures of effectiveness, cost, or cost-effectiveness and are normally used to rank or compare aircraft design or usage alternatives. Examples of "figures-of-merit" are shown in the table below.

TYPE	MEASURE	DIMENSIONS
Effectiveness FOM	o Weight o Attrition o Exchange Ratio o Combat Sortie Life	o Pounds per Aircraft o Losses per Thousand Sorties o Losses per Target Killed o Number of Sorties per Aircraft Lifetime
Cost and Cost-Effectiveness FOM	o Flyaway Cost Impact o Attrition Effects o Support Requirements o Program Effects o Force Impact	o Cost per Aircraft o Cost per Sortie or Cost per Target Killed o Cost per 10-year Operations o Life Cycle Cost per Aircraft o Aircraft Procured

5.5.1-1 Effectiveness FOMs - Those figures-of-merit that quantify benefits and penalties primarily in units of effectiveness. Cost considerations are either excluded or held constant at some explicit or implicit level, e.g., in a FOM quantifying the effectiveness achievable on a design-to-cost basis.

5.5.1-2 Cost FOMs - Those figures-of-merit that quantify benefits and penalties primarily in units of cost. Effectiveness considerations are either excluded or held constant at some explicit or implicit level (e.g., in a FOM quantifying the cost level achievable on a fixed-effectiveness-design basis).

5.5.1-3 Cost-Effectiveness FOMs - Those figures-of-merit that quantify overall benefits and penalties in units that include both cost and effectiveness, where both of these factors vary as functions of the specifics being evaluated. Except within a relatively narrow range of variation, one or the other of the variable factors is usually held constant and optimization is performed using the other factor.

5.5.1-4 S/V Trade Parameters - Those pertinent factors to be assessed in tradeoffs and selection of vulnerability reduction fixes, such as weight, cost, modification manhours, performance changes, maintainability, and reliability.

5.5.1-5 S/V Trade Benefits - Those improvements in aircraft survivability or vulnerability which are the result of resources expended, or alterations to the aircraft or its associated characteristics.

5.5.1-6 S/V Trade Penalties - Those resources which must be expended or undesirable alterations to the aircraft or associated characteristics which are required to obtain survivability enhancement.

5.5.2 Subfield Term: Merit Rating Systems (MRS)

Definition: Methodologies, including concepts, techniques, and procedures, for quantifying, combining, and interpreting figures-of-merit.

Explanatory Notes: "Merit rating systems" provide the means for combining appropriate figures-of-merit into singular measures that can be used to compare or rank alternatives. The first step in this process, depending upon the particular application, may involve converting the FOMs into intermediate measures such as penalty or benefit factors. These factors are then combined in some manner (added, multiplied, etc.) to yield a merit rating of an aircraft design or usage alternative. The conversion of FOMs into penalty or benefit factors allows for the incorporation of desirable trends or boundary conditions without modifying or perturbing the basic design or usage-related FOMs.

5.5.2-1 Effectiveness MRSs - MRSs that center on effectiveness figures-of-merit.

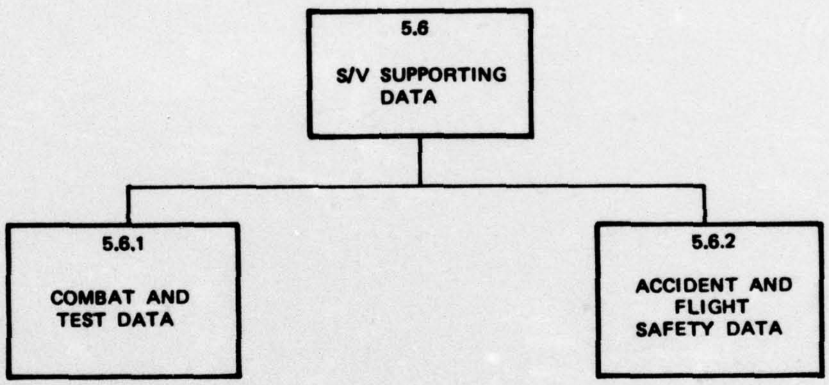
5.5.2-2 Cost MRSs - MRSs that center on cost figures-of-merit.

5.5.2-3 Cost-Effectiveness MRSs - MRSs that center on cost-effectiveness figures-of-merit.

5.6 Topical Field Term: S/V Supporting Data

Definition: Empirical data that quantifies, describes, characterizes, or in some other respect provides insight into any aspect of survivability or vulnerability.

Explanatory Notes: The data itself may provide the desired insight into the S/V aspects of interest, or results from the analysis of such data may be required. This topical field is subdivided as shown below.



5.6.1 Subfield Term: S/V Combat and Test Data

Definition: Empirical data derived from observation of planned experiments, combat activities, or post-combat operations.

Explanatory Notes: These data come from a wide variety of sources and situations. It is essential to establish procedures ensuring that the pertinent data are obtained expeditiously and analyzed thoroughly. Through proper collection and analysis, the various S/V test and combat results can be defined, described, delineated, distinguished, quantified, and statistically characterized for further use.

5.6.1-1 Controlled-Damage Tests - Tests designed to determine a basis for estimating the damage and failure modes of a test specimen (component, subsystem, configuration, etc.) without destroying the specimen.

5.6.1-2 Replica Targets - Targets fabricated for testing which are representative of aircraft structures, assemblies, etc. The test data on these targets can be extrapolated to establish pertinent S/V characteristics of represented parts on an aircraft.

5.6.1-3 Fragment Simulating Projectile - A projectile designed with special shape and size for ballistic test firings so that the effect of typical fragments from high-explosive shells can be simulated.

5.6.1-4 Function Plate - A plate, of varying thickness and material, placed in front of the test specimen at different distances, and is the first object impacted by a test-fired projectile. The plate may be: (1) designed to test the sensitivity of the projectile fuzing; (2) placed to determine the effect of spacing between the skin and an internal unit; or (3) used to detonate a projectile to determine the effect of damage mechanisms on an internal unit.

5.6.1-5 Fair Impact - The result when an unyawed projectile strikes an unsupported area of a ballistic test sample at an undamaged location which is at least three calibers away from a previous impact, hole, crack, edge of sample, or spalled area. Only fair impacts are permitted for rounds used in determining the ballistic limit.

5.6.1-6 Complete penetration - A fair impact when the projectile or fragment of the projectile or fragment of the armor test sample is thrown beyond the rear of the sample with sufficient energy to perforate a 0.020-inch 2024-T3 aluminum alloy witness plate placed parallel to and 6 inches beyond the armor test sample. This definition relates to a "protection ballistic limit" (see 5.3.2.1.2-9).

5.6.1-7 Partial Penetration - Any fair impact that rebounds from the armor plate, remains imbedded in the target, or passes through the target but with insufficient energy to pierce or cause the sample to pierce the 0.020-inch-thick 2024-T3 aluminum alloy witness plate. This definition relates to a "protection ballistic limit" (see 5.3.2.1.2-9).

5.6.1-8 Witness Plate - A plate located behind a test sample to determine the extent of penetration by a projectile. If the witness plate evidences any damage, complete penetration (see 5.6.1-6) of the sample is accomplished; if no damage to the witness plate can be observed, only partial penetration (see 5.6.1-7) of the sample has occurred.

5.6.1-9 Test Simulation Accuracy - A qualitative assessment of the degree of similarity between the test sample and the test environment as compared to the element installed on the aircraft and the combat environment.

5.6.1-10 Extrapolation Validity - The degree of confidence which must be exercised in estimating the S/V characteristics of an aircraft element based on the test results obtained from the test unit.

5.6.1-11 Combat Incident - An encounter in a combat environment during which a threat fires upon an aircraft. Evidence of the threat firing can be the result of visual observations of firing or impacts noticed by the aircraft crew during the encounter.

5.6.1-12 Combat Hit - A combat incident that results in damage to the aircraft involved, caused by a threat mechanism.

5.6.1-13 Combat Hit Rate - The percentage of encounters with threats firing in which the aircraft is hit.

5.6.1-14 Combat Loss Rate - A measure of percentage of aircraft losses resulting from their operations in a combat environment. This term is generally expressed in losses per thousand sorties - i.e., a loss rate of three is used to denote three aircraft losses resulting from 1000 sorties.

5.6.1-15 Combat Repair Time - The total time, in manhours and/or clock hours, required to repair a target or component that is damaged by a threat.

5.6.1-16 Combat Loss Ratio - The number of ground targets killed per aircraft loss.

5.6.2 Subfield Term: Accident and Flight Safety Data

Definition: Empirical data derived from reports of non-combat related accidents.

Explanatory Notes: Accident and flight safety data are those data gleaned from accident and flight safety reports which provide information about strengths of materials, causes of component failure, effects of stress, etc.

ORGNNIZATIONAL INDEX OF TERMS

ALPHABETICAL INDEX OF TERMS

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